New Scientist

16/23 December 2023

2023 IN REVIEW
WEIGHT-LOSS WONDER DRUGS
THE RISE OF CHATBOTS
HOTTEST YEAR EVER
INDIA'S MOON LANDING
INCREDIBLE SPACE PICS

CHRISTMAS & NEW YEAR SPECIAL

Our future AI overlords
When octopuses dream
Mystery of the quantum lentils
Meet the iceberg cowboys
The physics of cocktails
Vampire bats on a treadmill
A very modern medieval map
Extreme microbes in your kitchen
Will Earth outlive the sun?
Putting flavour-bridging theory to the test
Scientific words of the year
Glass of orca milk, anyone?

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AND SO MUCH MORE INSIDE!
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SCAN ME

This week's issue

Christmas & New Year special

Vol 260 No 3469/70
Cover image: Brett Ryder

Dear reader,
Welcome to our traditional, fun-filled holiday double issue, replete with lentils that communicate electromagnetically (yes, really!), spiders dreaming, an original story from science fiction powerhouse Alastair Reynolds, fiendish games and puzzles, ancient maps, bizarre flavour pairings, the physics of cocktails and so many other seasonal treats! Add to that our news review of the year, and you have the perfect companion for the festive season. Here's wishing you a happy holiday wherever you are.

Emily Wilson
New Scientist editor-in-chief

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Instant Expert: Brain

Join six leading brain scientists on 10 February 2024 as they reveal – via the latest research in neuroscience, psychology and physiology – what is going on in our heads when we think, feel and communicate. Gain insights on how to boost your cognitive performance and live a healthier, happier life. For 2024, we have cut ticket prices and introduced a new "super early bird" option for our Instant Expert events, which will be held at London's Conway Hall.

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Tour

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Video

Secrets of Stonehenge

Stonehenge is one of the world's most famous prehistoric monuments. As a site of possible ceremonial, astronomical or spiritual events, it remains a subject of intrigue. Now, using the latest scientific technologies such as radiocarbon dating and 3D laser scanning, archaeologists are understanding more about how this colossal stone circle was built and what its purpose was, as well as gaining new insights into how our human ancestors lived.

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Jessica Comi (left) and MSF surgeon Dr Federica Lezzi extract a bullet from a patient shot just above the knee during fighting in the Sudanese capital. Bashair hospital, Khartoum, 13 May. Photograph © Ala Kheir/MSF

JESSICA COMI IS AN OPERATING THEATRE NURSE WHO WORKED FOR MSF IN KHARTOUM, SUDAN.

"We arrived in Khartoum on a Monday and started operating at noon the following day. The first week was incredibly challenging.

Every time we heard explosions, we got ready for a mass casualty incident – a situation where lots of wounded people arrive at the same time. You never know if it will be 20 or 40 or 100 patients. One day, 127 patients arrived in a short space of time after a series of explosions.

Very quickly we were inundated with wounded men, women and children. Seventeen people were dead on arrival. The emergency room was full, the two operating theatres were full. In one theatre, we were trying to manage the most complex cases; in the second, we were working on cases that were a bit less complicated. That day, we ran the operating theatres until four or five in the morning. We worked non-stop.

War surgery is complicated. Working with wounded patients brings a lot of challenges and, if you aren't used to doing this type of surgery, it can be especially difficult. You need to know the potential risk for a patient if they are not treated immediately – risks such as infections or losing a limb or haemorrhaging. Bullets and shrapnel are dirty and they create massive wounds, so in a war zone you treat every single wound as already infected. These injuries are complex and you need to act quickly. Our team was experienced and that expertise made a big difference.

Depending on the kind of wound, some patients need multiple surgeries and can take many days to recover. Others may need even longer treatment – taking weeks or sometimes months.

As the conflict continued and more people heard that the hospital was open, we started to see more patients, particularly women and children.

I have worked a lot in war zones, and this was probably my most challenging assignment. But it was very special how the team worked through the challenges together. You could feel that we were all working for one reason – and that was to save lives."

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A year of two stories

This year, the full impacts of AI became obvious, but the biggest story was still global warming

VUK VALCIC/ALAMY

WHEN *New Scientist* editors sat down to discuss the biggest story of 2023, one topic shot straight to the top of the list. It can't have escaped anyone's notice that artificial intelligence rocketed to prominence this year, with OpenAI, the maker of ChatGPT, becoming a household name. Hundreds of millions of people are now using large language models on a regular basis, in a rapid roll-out of technology that is essentially unprecedented. And while only a fraction of that number are using image and video-generating AIs, that still amounts to millions of new creations every single day.

Beyond consumer use of AI, the technology is also transforming huge swathes of science. This year alone, we have reported on advances in weather forecasting, materials science, archaeology, chemistry and many, many more fields. It is safe to say that, for good or for ill, the AI revolution has only just begun (see page 22).

Another topic was already at the top of our list. Climate change is the biggest story of the year, the decade, the century – but 2023 went beyond anyone's expectations. Although the figures won't officially be determined until January 2024, it is pretty safe to say that this year was the hottest on record, and it may also be the first year in which global average temperatures rose 1.5°C above pre-industrial baselines – a monumental failure in our efforts to halt warming (see page 16).

We had the hottest day on record globally on 3 July, only for that record to be broken again on 4, 5 and 6 July, in what became the hottest month ever. And with the heat came disasters. Canada had its worst ever year for wildfires, which released huge amounts of carbon into the atmosphere and generated massive air pollution across vast areas.

Meanwhile, in the US, there were 25 weather disasters that had losses exceeding $1 billion by 8 November, beating the annual record of 22 set in 2020. This year's total includes the August wildfires in Hawaii that killed more than 100 people. In September, heavy rains caused two dams to collapse in Libya, killing as many as 20,000 people in the city of Derna. The list could go on and on.

> **"Decisions made today on AI and climate change could determine the fate of billions of people"**

What connects the stories of AI and climate change is that decisions taken today could potentially determine the fate of billions of people. With AI, the long-predicted rise of software taking people's jobs may have finally arrived, with some businesses finding that, for example, employing someone to babysit ChatGPT as it churns out copy is more cost-effective than employing a team of humans – although whether that output is of the same quality remains up for debate.

Perhaps unsurprisingly, given Hollywood's long history of producing AI dystopias, it was the US movie industry that saw one of the biggest push-backs against the machines, with both writing and acting unions going on strike for months (see picture, above). While AI wasn't their only grievance, it did play a big role in negotiations, with writers wanting assurance that their work wouldn't be used to train AIs to pump out blockbusters. Meanwhile, actors were concerned about having their likenesses scanned into a computer and puppeted by an AI, leaving them out of work for future roles.

With concerns about AI running high, the UK attempted to take the lead on regulating the new technology. Prime Minister Rishi Sunak hosted global dignitaries, business leaders and AI experts at the AI Safety Summit in Bletchley Park, resulting in the Bletchley Declaration, an agreement signed by 28 countries and the European Union. While international cooperation is to be welcomed, the main substance of the document was to set out to host further meetings, in a pace that seems at odds with a technology that seemingly transforms the world every few months. If we are to ensure that AI benefits everyone, not just the firms behind it, politicians must act faster.

That is a refrain we can echo when it comes to climate change as well. In 2015, nations at the COP21 summit in Paris pledged to keep warming from greenhouse gas emissions below 1.5°C. This is a goal that has been echoed at every COP since – including COP28 in Dubai, which was concluding as this issue went to press – despite the lack of action to match it. Indeed, it now seems that remaining below 1.5°C of warming, while not impossible according to the laws of physics, will be politically, socially and technologically out of reach. That is because global greenhouse gas emissions have continued to rise since 2015, with 2023 up by more than 1 per cent on 2022. We are currently on track for nearly 3°C of warming by 2100, according to a report published in November.

What is really worrying is that weather disasters fuelled by global warming are becoming so frequent and severe that some places aren't able to fully recover. In July, the United Nations Office for Disaster Risk Reduction said that hard-won social and economic advances are being reversed by disasters because of their effects on food security, employment and education.

As we turn to 2024, there will be new opportunities to tackle the twin issues of AI and climate change. Depending on exactly how you count it, around 3.5 billion people – or almost half the population of the planet – will be voting in elections next year. These include elections in India (the world's largest democracy), the US, the EU and most likely the UK. (Technically, the deadline for its general election is January 2025.)

Already, there are concerns that AI could play a role in disrupting some of these elections, given the risk of the internet being flooded with misinformation and fake videos. Even if that doesn't come to pass, the leaders installed next year will increasingly have to tackle AI head-on, as we can expect the technology to accelerate throughout their terms.

But despite some people's fears that AI could take over the world and exterminate humanity (see page 56), climate change must always be at the top of the political agenda. Those elected next year will govern during a vital period on the road to net zero by 2050, as we reach the midpoint of that journey. Currently, efforts to tackle emissions are still lacking. If we take anything from the extraordinary heat of 2023, let it be that this must finally change. ▮

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AI can tell which chateau Bordeaux wines are from p15

Marine biology

Santa fishes you a merry Christmas

Feeding time got festive in the large saltwater aquarium at the Multimar Wattforum in Tönning, Germany. Timo Kaminski, head of animal care, dressed up as Santa Claus – and in scuba gear – to bring gifts of mackerel and scampi to the inhabitants of the 250,000-litre aquarium.

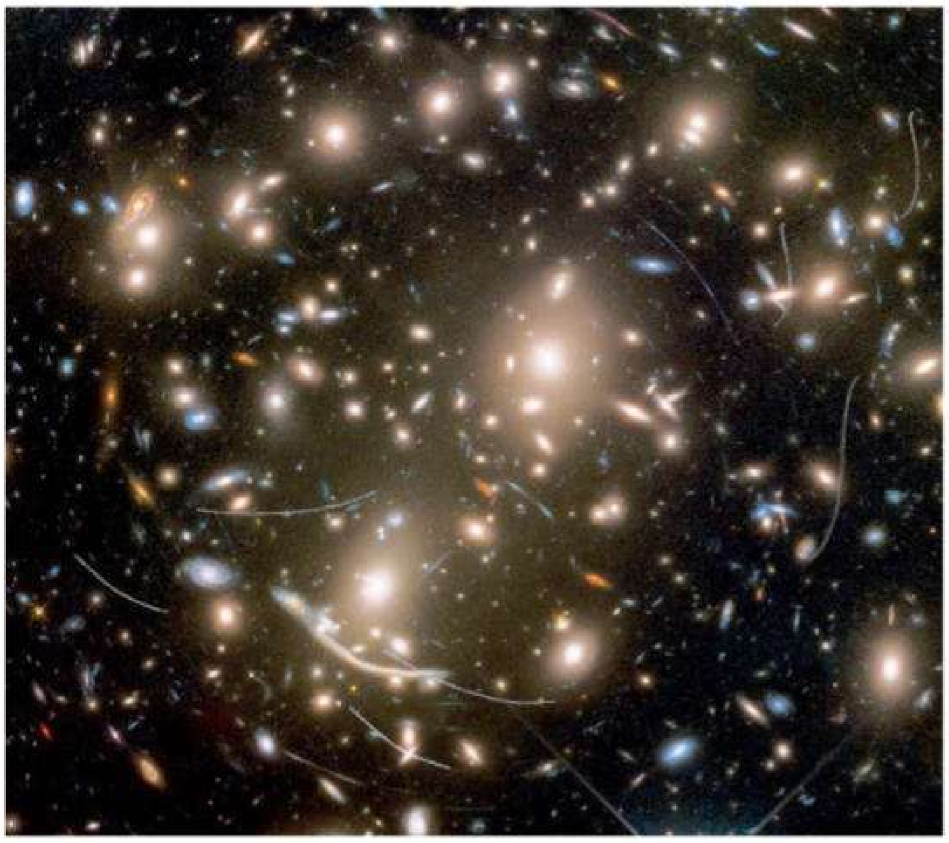
FRANK MOLTER/DPA PICTURE ALLIANCE/ALAMY LIVE NEWS

Astronomy

A problem with cosmic clumps

Material in the nearby universe seems less clustered than we think it should be

Leah Crane



NASA, ESA, AND B. SUNNQUIST AND J. MACK (STSCI)

Abell 370 is a distant collection of several hundred galaxies

WE DON'T know how clumpy the universe is. A survey of more than 25 million galaxies has found a discrepancy between the two main ways to measure how matter is clustered, suggesting that there is something wrong with the widely accepted standard model of cosmology – our best understanding of the universe.

The work looked at three years of data from the Hyper Suprime-Cam (HSC) programme, based at the Subaru telescope in Japan. Crucial to the finding was an effect called weak gravitational lensing, which occurs when light from other galaxies is stretched by the gravity of matter between those galaxies and our telescopes. This warps the apparent shapes of such galaxies and, by observing lots of them, researchers in the HSC collaboration could make inferences about the structure of matter in the universe.

What they found was an issue with a number called the S8 parameter, which measures the lumpiness of the distribution of matter in the cosmos.

There are two main ways to calculate S8. The first is by observing galaxies in the relatively nearby universe, which is what the HSC team did. The second is by observing fluctuations in the cosmic microwave background (CMB) – ancient light left over from the big bang – and then using the standard model of cosmology to simulate what the matter distribution should look like now. This was the approach taken by the Planck space observatory in earlier studies.

The CMB method results in an S8 value of about 0.83, but the HSC analysis puts it at about 0.77, meaning matter is less clustered (*Physical Review D*, in press). It is a small difference, but it could have big consequences in terms of our understanding of the universe.

"We've already seen hints of a discrepancy in other lensing experiments, and this confirms it," says Roohi Dalal at Princeton University, a member of the HSC collaboration. "We're now at a stage where we really have to understand what's causing those low values."

Wiggle room

There are three main collaborations measuring S8 via gravitational microlensing, and all three have found similar results. That makes the latest finding more robust, but it isn't set in stone yet, says Bhuvnesh Jain at the University of Pennsylvania, who is part of one of the other collaborations, the Dark Energy Survey. There could be other explanations for the findings, such as a common flaw in these surveys.

"It's not completely ruled out that we're all making a related mistake," he says. "There's a little bit of overlap in the calibrating and the methodology, so that's my biggest worry."

The question of whether tension between the gravitational lensing and CMB methods of measuring S8 has a physical cause or is simply due to some statistical error should be answered in the coming years, though. Several new telescopes, including the Vera C. Rubin Observatory in Chile, are due to start working soon and will provide data on enormous samples of galaxies, with 10 times the resolution of any of the current gravitational microlensing experiments.

"This [HSC] data is extremely important because it is the most similar to what we'll get from the Vera C. Rubin survey," says Michael Troxel at Duke University in North Carolina, also part of the Dark Energy Survey collaboration. "If there really is something there to find, we will find it with these next surveys, and this dataset is really the most important one to prepare for those new calibrations."

25m

Number of galaxies surveyed to measure the S8 parameter

If the S8 measurements from HSC and the other gravitational microlensing tests are correct, it means that we have some sort of fundamental misunderstanding of the properties of the universe, but it isn't yet clear where that mix-up could lie.

"Maybe there's slightly less of some matter species or a bit more, or our understanding of the dynamics of dark matter clustering is a little bit incorrect," says Troxel. Weak gravitational lensing is particularly tied to understanding the distribution of dark matter because the only way we can locate such matter is by observing its gravitational effects.

So-called dark energy could also be a factor. "If our understanding of dark energy as a cosmological constant isn't right or there's some small time evolution component to the properties of dark energy, that would explain it," says Troxel.

The problem could even be something a little less exotic, says Dalal. "For example, we don't know how things like jets from supermassive black holes work, so it's possible that our models don't account for the full range of possibilities, and if things like those outflows work differently, that could change our expected values of S8," she says.

Once these results are checked by the next generation of huge telescopes, we can start getting to work on tweaking our understanding of cosmology in an effort to resolve the S8 tension – without breaking anything else. ▮

Ageing

Having children earlier in life is genetically linked to dying younger

Chen Ly

PEOPLE who are genetically predisposed to having children earlier in life are less likely to live to the age of 76, according to an analysis of more than 270,000 people's genomes.

Why we age is one of the biggest evolutionary mysteries. You might assume that natural selection would lead to people passing on genes that help you live longer, thus giving more time to reproduce, but there has been no evidence to support this.

One of the leading explanations for this lack of evidence is that genetic mutations that favour reproducing earlier in life could also result in a shorter lifespan, an idea called antagonistic pleiotropy.

"It's because natural selection largely cares about reproduction," says Jianzhi Zhang at the University of Michigan. "So those mutations that are beneficial for reproduction but may be detrimental afterwards would still be selected."

Seeking evidence relating to antagonistic pleiotropy, Zhang and Erping Long at the Chinese Academy of Medical Sciences analysed genomes from 276,406 people in the UK Biobank, a long-term health study. The selected participants were born between 1940 and 1969 and were of European ancestry.

HALFPOINT IMAGES/GETTY IMAGES

There seems to be a link between the age you have children and your lifespan

For each person, the researchers calculated a polygenic score, an assessment of a mix of genetic variants linked to better reproductive health in early life. The higher someone's score, the more likely they were to be fertile for longer. They also collected information on lifespan: either how long the participants lived or how long their parents lived for those who were still alive.

Zhang and Long found that people who had higher polygenic scores for reproductive health had a lower probability of living to 76 years old (*Science Advances*, doi.org/k745). There was no specific reason for using this age as a cut-off, says Zhang.

Those born earlier also tended to have a lower polygenic score than those born closer to 1969, suggesting that traits that enhance reproduction are still being selected despite their impact on longevity, says Zhang.

"Our findings are in strong support of the antagonistic pleiotropy hypothesis," he says. One potential mechanism is that some gene variants that enhance reproductive attributes may result in disease later in life. For example, one such variant, rs12203592, has been linked to cancers.

"[It is the] first strong evidence of antagonistic pleiotropy in humans, supporting a major pillar of evolutionary ageing theory," says Steven Austad at the University of Alabama at Birmingham.

"Whether our results apply to African or Asian people, we don't know yet, but I think we can expect to see this pattern," says Zhang.

It is also important to note that other factors, including medical advances, have led people to live longer and have fewer children, on average, says Zhang. "Genetic changes are minute compared to environmental factors." ▮

Zoology

Unusual hedgehog from eastern China is new to science

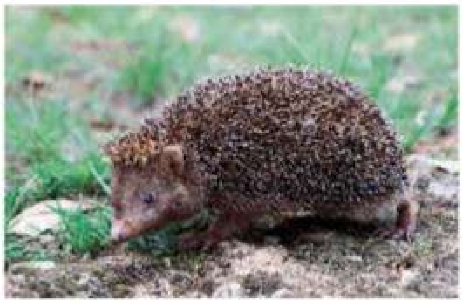
A DARK brown hedgehog that dwells in the forests of eastern China has been scientifically described for the first time.

In 2018, Kai He at Guangzhou University, China, and his colleagues saw unusual-looking hedgehogs in the provinces of Anhui and Zhejiang. They had darker brown fur and spines, as well as slightly larger ears, than the European hedgehog (*Erinaceus europaeus*).

After analysing seven of the animals, including their DNA samples, the researchers concluded that they belonged to a new species, which they named *Mesechinus orientalis*.

The four other known species in the *Mesechinus* genus mainly live in northern China, Mongolia and Russia, while *Mesechinus hughi* resides in south-west China. The other types live more than 1000 kilometres away, says He.

Weighing just under 340 grams and measuring 18.8 centimetres long, on average, *M. orientalis* is slightly smaller than the other known hedgehogs in its genus. Like other hedgehogs, it is nocturnal and tends to feed on insects and fruit. It also hibernates during winter (*ZooKeys*, doi.org/k74g).



ZOOKEYS

This hedgehog has darker brown fur and spines, and slightly larger ears, than European hedgehogs

So far, the team has found *M. orientalis* in only two Chinese provinces. Based on the numbers recorded, though, it isn't thought to be endangered, says He.

Previously, there were only 17 known species of hedgehogs, "so we were pretty happy that we increased that by one", he says.

"For a genuine hedgehog nerd like myself, this is astonishing news," says Sophie Lund Rasmussen at the University of Oxford. "I look forward to learning more about the species' ecology." ▮

Chen Ly

Mathematics

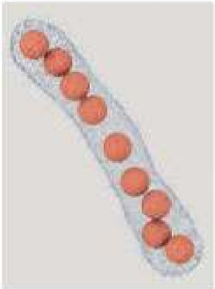
Tiny plastic balls confirm the best way to pack a few spheres is in a sausage

Alex Wilkins

WHAT is the most space-efficient way to pack tennis balls or oranges? Mathematicians have studied this "sphere-packing" problem for centuries, but surprisingly little attention has been paid to replicating the results in the real world. Now, physical experiments involving microscopic plastic balls have confirmed what mathematicians had long suspected – with a small number of balls, it is best to stick them in a sausage.

Johannes Kepler was the first person to tackle sphere packing, suggesting in 1611 that a pyramid would be the best way to pack cannonballs for long voyages, but this answer was only fully proven by mathematicians in 2014.

This proof only considers the best way of arranging an infinite number of spheres, however. For finite sphere packings, simply placing the balls in a line, or sausage, is more efficient until there are around 56 spheres. At this point, the balls experience what mathematicians call the "sausage catastrophe" and something closer to pyramid packing becomes more efficient.



MARÍN-AGUILAR, ET AL. 2023

A simulation shows nine microscopic balls packed inside a cell membrane

But what about back in the real world? Sphere-packing theories assume that the balls are perfectly hard and don't attract or repel each other, but this is rarely true in real life – think of the squish of a tennis ball or an orange.

One exception is microscopic polystyrene balls, which are very hard and basically inert. Hanumantha Rao Vutukuri at the University of Twente in the Netherlands and his team, who were unaware of mathematical sphere-packing theories, were experimenting with inserting these balls into empty cell membranes and were surprised to find them forming sausages.

"One of my students observed a linear packing, but it was quite puzzling," says Vutukuri. "We thought that there was some fluke, so he repeated it a couple of times and every time he observed similar results," says Vutukuri. "I was wondering, 'why is this happening?' It's a bit counterintuitive."

After reading up on sphere packing, Vutukuri and his team decided to investigate and carried out simulations for different numbers of polystyrene balls in a bag. They then compared their predictions with experiments using up to nine real polystyrene balls that had been squeezed into cell membranes immersed in a liquid solution. They could then shrink-wrap the balls by changing the concentration of the solution, causing the membranes to tighten, and see what formation the balls settled in using a microscope.

> **"For up to nine spheres, we showed experimentally and in simulations that the sausage is the best"**

"For up to nine spheres, we showed, both experimentally and in simulations, that the sausage is the best packed," says team member Marjolein Dijkstra at Utrecht University, the Netherlands. With more than nine balls, the membrane became deformed by the pressure of the balls. The team ran simulations for up to 150 balls and reproduced the sausage catastrophe, where it suddenly becomes more efficient to pack things in polyhedrons, with between 56 and 70 balls (*Nature Communications*, doi.org/k738).

The sausage formation for a small number of balls is unintuitive, says Erich Müller at Imperial College London, but makes sense because of the large surface area of the membrane with respect to the balls at low numbers. "When dimensions become really, really small, then the wall effects become very important," he says.

The findings could have applications in drug delivery, such as how to most efficiently fit hard antibiotic molecules, like gold, inside cell-like membranes, but the work doesn't obviously translate at this point, says Müller. ▮

Zoology

Jumping spiders seem to be able to recognise each other

SOME spiders appear to be capable of telling each other apart. It is important for social animals to be able to recognise individuals within their species, but only a few invertebrates have been observed to have this ability, including northern paper wasps (*Polistes fuscatus*), which live in colonies.

Now, Christoph Dahl at the University of Neuchatel in Switzerland and Yaling Cheng at Taipei Medical University in Taiwan have found that a species of jumping spider known as the regal jumper (*Phidippus regius*) may also be able to distinguish between each other.

Dahl and Cheng divided 20 regal jumpers into pairs. Each pair was put in a container separated by a transparent panel, so the spiders could see each other but not make physical contact. They then seemed to approach each other, a sign that they were interested in making an initial encounter.

After 7 minutes, Dahl and Cheng replaced the transparent panel with an opaque one, visually separating the spiders. Three minutes later, they returned to the transparent panel. The test was done many times, so the paired spiders were sometimes strangers and sometimes weren't.

FLPA/ALAMY

Regal jumping spiders engaging in a courtship display before mating

When the spiders saw an individual they had already seen, they tended to stay further apart, compared with their first meeting. "They showed a little bit less interest," says Dahl. But if they were exposed to a new individual, they approached each other (bioRxiv, doi.org/k74b).

The spiders consistently showed less interest in those they had seen before, so they seem to have some form of memory and recognition for individuals, says Dahl. ▮

Chen Ly

Ecology

Great Wall of China is protected by a coat of lichen and moss

James Woodford

THE Great Wall of China is being protected from erosion by a "biocrust" of moss, lichen and cyanobacteria, much as the wall once shielded the country from northern invasions.

The wall, built and rebuilt many times between about 200 BC and the Ming dynasty, which lasted from 1368 until 1644, once stretched for more than 8800 kilometres. Today, less than 6 per cent of its total length remains well-preserved, and much has vanished.

Many sections of the wall were built with rammed earth, which is when natural materials such as soil and gravel are compacted to create structures.

Bo Xiao at China Agricultural University in Beijing and his colleagues have sampled a 600-kilometre-long section of the wall and observed that more than two-thirds of it is covered in biocrust. The team found that this layer of lichens, mosses and cyanobacteria contributes to strengthening the wall, keeping it dry and protected from wind and water erosion. The biocrust also acts as an insulator, reducing temperature extremes and lowering the effects of salinity.

Biocrust-covered sections were less porous, with reduced water-holding capacity, erodibility and salinity, says the team. These areas also showed increased resistance to various forms of mechanical assault (*Science Advances*, doi.org/k8df).

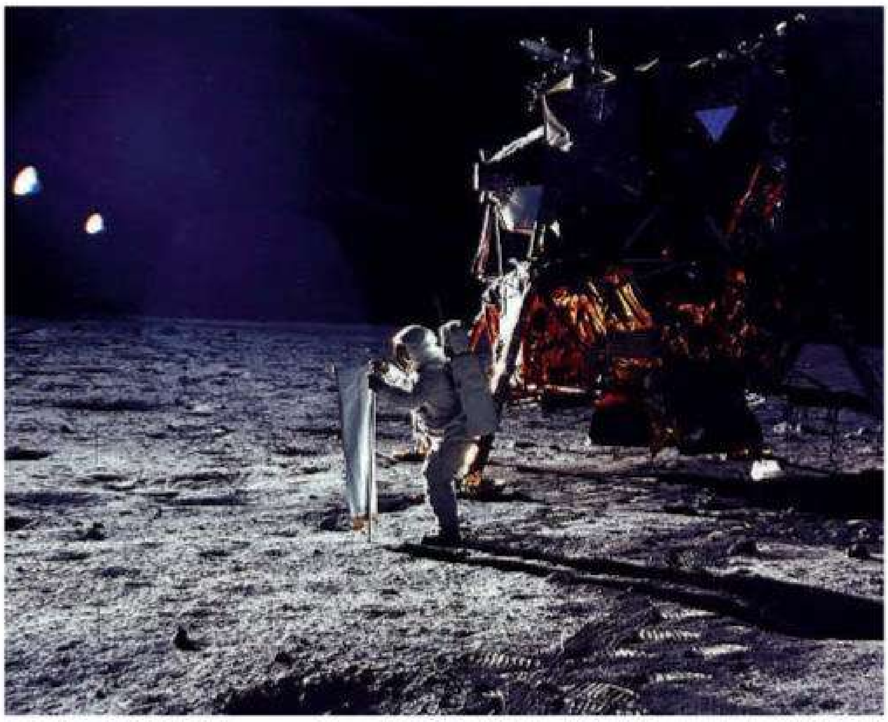
The findings could change the way managers of heritage sites around the world regard vegetation on ancient structures, says Xiao.

The biocrusts may mitigate the extremes of hot and cold the wall faces, says Brett Summerell at the Botanic Gardens of Sydney. "They would provide an environment that helps buffer and protect the stability of the structure of the walls."

Geology

The moon may enter a new geological period thanks to us

Matthew Sparkes



NASA

US astronaut Buzz Aldrin on the surface of the moon in 1969

HUMANITY'S influence on the moon is so great that we should define a new geological epoch, just as we are doing on Earth by creating the Anthropocene, argue researchers.

The Anthropocene is the name given to the epoch in which humans began having a significant impact on Earth's geology and ecosystems. Most researchers suggest Earth entered this period in 1950, marked by the presence of plutonium isotopes from nuclear weapons tests in sediments of a relatively untouched lake in Canada.

Now, Justin Allen Holcomb at the University of Kansas and his colleagues say the moon has entered its own Anthropocene, as the effects of spacecraft, lunar rovers and other human activity displace more surface regolith than natural processes such as meteoroid impacts (*Nature Geoscience*, doi.org/k74h).

Humans began having an effect on the moon in September 1959 when the Soviet Union crash-landed its Luna 2 probe on the surface, leaving a crater. India became the fourth country to make a soft landing on the moon this year, and a range of national and private missions are planned in the near future. To date, we have caused surface disturbances in at least 59 locations on the moon and have discarded objects including spacecraft components, flags, golf balls and bags of human excrement.

1959

When humans began to have an effect on the moon

Holcomb says the weight of human-made objects left on the moon and the amount of regolith displaced are both likely to dramatically increase in the coming years as colonisation and mining efforts begin.

"We really do need to slow down and talk about what the consequences are," he says.

Ingo Waldmann at University College London says that the moon has certainly entered its equivalent of the Anthropocene, because lunar geology isn't very dramatic: weak quakes happen sporadically and water is only deposited in the surface regolith over aeons by solar winds.

"There might be an [asteroid] impact once every couple of million years or so," he says. "But apart from that, not much happens." Just us walking on it has a bigger environmental impact than anything that would happen in hundreds of thousands of years, he says.

The current lunar geological division, the Copernican Period, dates back to more than a billion years ago. By contrast, Earth has passed through about 15 geological periods in this time.

Waldmann is concerned that missions such as NASA's Artemis III, which aims to put astronauts on the moon for the first time since Apollo 17 in 1972, will contaminate the lunar surface. He says there should be an international agreement for the creation of the equivalent of a national park on the moon.

"The lunar surface is the most pristine environment that we have access to, because the regolith builds up so slowly and erosion happens so slowly that you do have the whole imprint of the solar system on the moon as geological records, which we don't have on the Earth," says Waldmann.

Mark Sephton at Imperial College London supports the proposal, but says a balance is needed. You want to at least have the equivalents of national parks that can be used to study the moon's history, he says. "But at the same time, human beings need to explore and move out into the solar system."

Health

Removing zombie cells may help MS

Senolytic drugs can remove damaged cells, allowing degraded tissue around nerves to recover

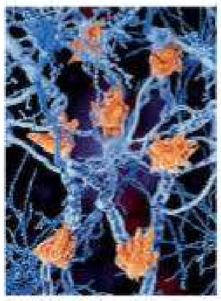
Grace Wade

DRUGS that remove worn and damaged immune cells may help treat multiple sclerosis (MS), a study in mice suggests.

MS is a neurodegenerative disease in which the immune system mistakenly attacks the protective coating around nerves, called myelin. It often manifests in people's 20s and 30s. Most people with the condition have relapses – where myelin is damaged and their symptoms worsen – followed by periods of recovery, in which myelin regenerates.

As people with MS age, they usually advance to the progressive phase. This is when symptoms worsen without recovery periods, meaning less myelin regenerates, says Phillip Gross at Georgetown University in Washington DC.

To see why remyelination typically occurs only earlier in the disease, Gross and his colleagues looked at the effects of senescent cells, which accumulate with age. These are cells that have become so worn or damaged they cease to work. Instead of dying, they linger in tissues, like cellular zombies. "We wanted to see if there was an increase in senescent cells with age following demyelination," says Gross.


JUAN GAERTNER/SHUTTERSTOCK

In multiple sclerosis, microglia cells (orange) damage the protective sheath around nerve cells

First, the researchers damaged myelin in five 3-month-old mice and four 18-month-old mice by injecting a toxin into their spinal cords. They then genetically analysed cells at the site of injury and found, on average, a sixfold increase in a marker of senescence in cells of the older mice than in those of the younger mice. The increase was greatest in microglia, which are immune cells of the nervous system.

This finding suggests a myelin injury leads to a greater build-up of senescent immune cells in older animals than in younger ones. Further experiments revealed that this increase seemed to impair the ability to regenerate myelin.

To see if targeting senescent immune cells could help repair myelin in old age, the researchers injected a toxin into the spinal cords of 11 mice aged 12 months. They treated five of them with a drug belonging to a class of medications known as senolytics, which remove senescent cells. The medication is in clinical trials and isn't yet used in humans. The other animals had a sham treatment.

They found, on average, a 65 per cent greater increase in a protein used to rebuild myelin in treated mice than in those in the control group. This suggests that clearing senescent immune cells may enhance myelin regeneration, says Gross, who presented these findings at a November meeting of the Society for Neuroscience in Washington DC.

> **"If we can improve the remyelination phase, maybe that's another way to treat multiple sclerosis"**

This could provide a different way to treat MS. "If we can improve that remyelination phase, maybe that's another way to attack the problem," says Gross.

Further research will be needed to find out whether senescent-clearing drugs could be effective at treating the disease in people, says Darren Baker at the Mayo Clinic in Minnesota. ▮

Conservation

Insects thrive on solar farms planted with native flowers

MICHAEL MCKINNE/ALAMY

Flowers planted among solar panels can attract butterflies and other insects

SOWING grasses and wildflowers among solar panels can bring big increases in bees and aid crop pollination in nearby fields.

Leroy Walston at Argonne National Laboratory in Illinois and his colleagues have monitored the impact on insects after two solar farms in Minnesota were planted with native vegetation.

The solar farms were built in 2017 on land that was previously used to grow rows of crops. The entirety of both sites were sown with specially designed seed mixes, and smaller, experimental plots were sown again in 2018.

From annual summer surveys of the experimental plots, Walston's team found that the number of beneficial insects tripled and their diversity increased by 13 per cent from 2018 to 2022. There was a particularly big impact on native bees, with their numbers rising 20-fold over the study period.

The researchers also counted insects visiting flowers in adjacent soya bean fields, finding a comparable level of visits as there were in fields next to grasslands in a restoration programme. This suggests attracting pollinators to the solar sites has a spillover effect on nearby farmland (*Environmental Research Letters*, doi.org/k7ww).

"While we prefer solar energy projects avoid ecologically sensitive areas altogether, solar-pollinator habitat can be a means to mitigate some ecological impacts associated with the conversion of lands to solar energy," says Walston.

This study gets us closer to working out how best to establish and maintain native vegetation around solar arrays in ways that end up benefiting wildlife, says Zara Dowling at the University of Massachusetts Amherst. ▮

Gary Hartley

Astronomy

Giant stream of stars may reveal dark matter's secrets

Leah Crane

WE HAVE spotted the biggest stream of stars ever recorded. This tendril is very faint, but it and others like it could help us unveil the nature of dark matter.

The stream of stars, called the Giant Coma Stream, seems to float unmoored from any particular galaxy in the Coma galaxy cluster, about 300 million light years away from Earth. Javier Román at the University of Groningen in the Netherlands and his colleagues spotted it using the Jeanne Rich Telescope in California and the William Herschel Telescope in Spain.

The Giant Coma Stream measures just 81,000 light years wide, but is nearly 1.7 million light years long, making it the longest such stream ever spotted. It has an estimated mass about 68 million times that of the sun (*Astronomy & Astrophysics*, doi.org/k7wt).

The size and structure of the stream suggest that it was once a galaxy in its own right. "In the beginning, this was just an ordinary dwarf galaxy, but it fell into the cluster and the tidal forces stretched it into this thin structure," says Román. "To observe such a fragile structure in a galactic cluster is very striking, because this is a very violent environment in which galaxies interact with each other."

The very violence that created the stream of stars will probably destroy it within a few million years, he says. Before then, though, it could prove a useful tool for investigating dark matter.

According to the standard model of cosmology, dark matter should clump into "haloes". As the galaxies in the Coma cluster whip around one another, so, too, should these haloes. Eventually, some could barrel through the stream, leaving holes behind. Such perturbations in streams like this could be used to investigate the nature of the dark matter in the haloes, says Román. ■

The human brain

We now know why we find some jokes funny – thanks to *Seinfeld*

Brian Owens

EVERETT COLLECTION INC/ALAMY

The sitcom *Seinfeld* ran for nine seasons between 1989 and 1998

WHAT starts as a simple knock-knock joke can light up different regions of your brain, depending on whether you find the gag funny or just understand it. Scientists have gained a better appreciation of this process after monitoring people while they watched the popular sitcom *Seinfeld*.

Several parts of the cortex, the brain's outermost layer, are involved in processing humour, but Penny MacDonald at the University of Western Ontario in Canada and her colleagues thought that the role of another brain region was potentially being overlooked.

Deep in the brain is a structure called the striatum, which was once thought to be primarily involved in motor functions. More recently, we have learned it is connected to almost every region of the cortex and is practically "involved in everything", says MacDonald.

One part of the striatum, the dorsal striatum, contributes to our working memory as well as how we process language and ambiguity, while the ventral striatum is critical for reward processing and enjoyment. The researchers therefore thought that the dorsal striatum may be involved in understanding a joke, while the ventral striatum might regulate our appreciation of it.

To test this, they used functional magnetic resonance imaging scans to monitor the brains of 15 women and 11 men, aged 22 on average, as they heard and rated different jokes. For example: "Do you know why cannibals don't like clowns? Because they taste funny!" The participants' brain activity was also monitored while they watched an episode of *Seinfeld*.

Rewarding feeling

The results show that the researchers were partly correct: the ventral striatum is responsible for us appreciating a joke, but both the dorsal and ventral striatum are involved in understanding it (*The Journal of Neuroscience*, doi.org/k4mm).

By processing ambiguity, the dorsal striatum may help people interpret the meaning of a joke, says Ori Amir, a neuroscientist and comedian in Los Angeles.

The ventral striatum is involved in motivation, and therefore it may help people understand jokes by pushing them to comprehend the humour, says MacDonald. Even if a gag doesn't make you laugh out loud, "that feeling of mirth that you get when you 'get the joke' is rewarding enough to be motivation", says MacDonald.

Team member Maggie Prenger, also at the University of Western Ontario, wants to see if there are medical implications of humour comprehension. She is studying the social and emotional symptoms of neurodegenerative conditions such as Parkinson's disease, one of which can be difficulty understanding humour.

To learn more, Prenger is repeating the experiment in people with Parkinson's. "These are symptoms that really affect quality of life and relationships, so it's a really pertinent thing to study and one that has been overlooked," she says. ■

Physics

How the seams on a baseball can alter its trajectory

Karmela Padavic-Callaghan

A BASEBALL'S seams play an unexpectedly large role in shifting its journey in midair.

A typical baseball is covered in two saddle-shaped pieces of leather, usually hand-stitched together. How it flies after leaving a pitcher's hand depends on factors including its speed, its spin and even the weather. When it flies, the air molecules close to its surface form a slow-moving layer, called the boundary layer, that surrounds the ball. Later in the throw, this layer separates from the surface and forms a wake behind the baseball.

To study what effect the slightly raised stitched seams may have on this process, Barton Smith at Utah State University and his colleagues launched 72 baseballs many times each – for a total of more than 3000 throws. They varied the orientation of the seams and applied different amounts of spin to the ball, then analysed what happened as each ball passed through a smoke-filled container.

The movement of smoke particles revealed that seams can make the process by which the boundary layer separates uneven, which then makes the baseball's wake – and its motion – shift unexpectedly.

Whenever a baseball's axis of spin was tilted from the vertical, the boundary layer separated earlier at the seams on one side than the other, and this skewed the ball's wake and made its trajectory curve. The researchers found the magnitude of this effect to be comparable to the Magnus effect, which is already familiar to pitchers and involves a shift in the ball's trajectory due to its spin. The seams could shift the ball's trajectory by several additional centimetres in any direction over its 18.4-metre journey from the pitcher to the batter, Smith recently told a meeting of the American Physical Society Division of Fluid Dynamics in Washington DC. ■

Learning

Gesturing as you talk may help you speak languages like a local

Conor Feehly

IF YOU are trying to master a new language, making pronounced hand gestures could help you emphasise the correct parts of words.

In some tongues, certain syllables within words are enunciated with markedly more weight than others, known as lexical stress.

10-15%

The boost in learning "lexical stress" as a result of gesturing

Previous research suggests that the use of gestures can help people learn a new language, and now Xing Tian at New York University in Shanghai, China, and his colleagues have found that making hand movements also assists us in using lexical stress correctly.

Languages such as English commonly feature lexical stress. For example, the word "accent" involves more emphasis on the first syllable, "ac", than the second, "cent". Native speakers of Chinese dialects, however, don't use lexical stress and may therefore find it particularly difficult to learn languages that feature it.

To see if gestures could help, Tian and his team recruited 124 native Chinese speakers, aged between 18 and 28 years, most of whom watched videos of people performing up-and-down hand movements that were synced to recordings of the same English words. All of the words consisted of three syllables, with the lexical stress being equally distributed among the words to fall on either the first, middle or last syllables.

The participants were divided into four groups, three of which watched videos that featured gestures over every syllable of each word. In the first group, a more pronounced gesture was carried out over the stressed syllable, with smaller gestures for the other two syllables.

The second group featured the pronounced gesture over a syllable that isn't stressed, while the third had the same size gesture for each syllable. The fourth group saw videos that featured no gestures at all.

Participants were asked to press a key when they thought lexical stress was being applied to different words, both without the help of gesture videos and then with them.

Hand gestures may help you stress syllables that should be emphasised

DELMAINE DONSON/GETTY IMAGES

Matching up

Overall, any gesture helped the participants learn lexical stress, but when more pronounced gestures were matched to the stressed syllable, they were particularly good at identifying it (bioRxiv, doi.org/k7tc).

"In general, gestures help to learn lexical stress, but how much help depends on the nature of gestures," says Tian.

The research involved several experiments, which makes it difficult to combine the results. Nevertheless, Tian estimates that the use of gestures helped the participants identify lexical stress between 10 and 15 per cent more accurately compared with no gestures at all.

Tian says this improvement is impressive considering that the participants were tasked with learning a "new language feature" that they weren't familiar with.

A follow-up study exposed the same Chinese speakers to Russian words, with gestures being similarly helpful for learning lexical stress.

"Our findings highlight the functional role of gestures in enhancing speech learning, suggesting practical implications for language teaching and learning," the authors write in their paper. ■

Zoology

Honey-hunting birds answer human calls

BIRDS called honeyguides recognise the special signals used by local people as an invitation to cooperate. Greater honeyguides (*Indicator indicator*) lead humans to bees' nests so the people will break them open. While the humans collect the honey, the birds feast on beeswax and larvae.

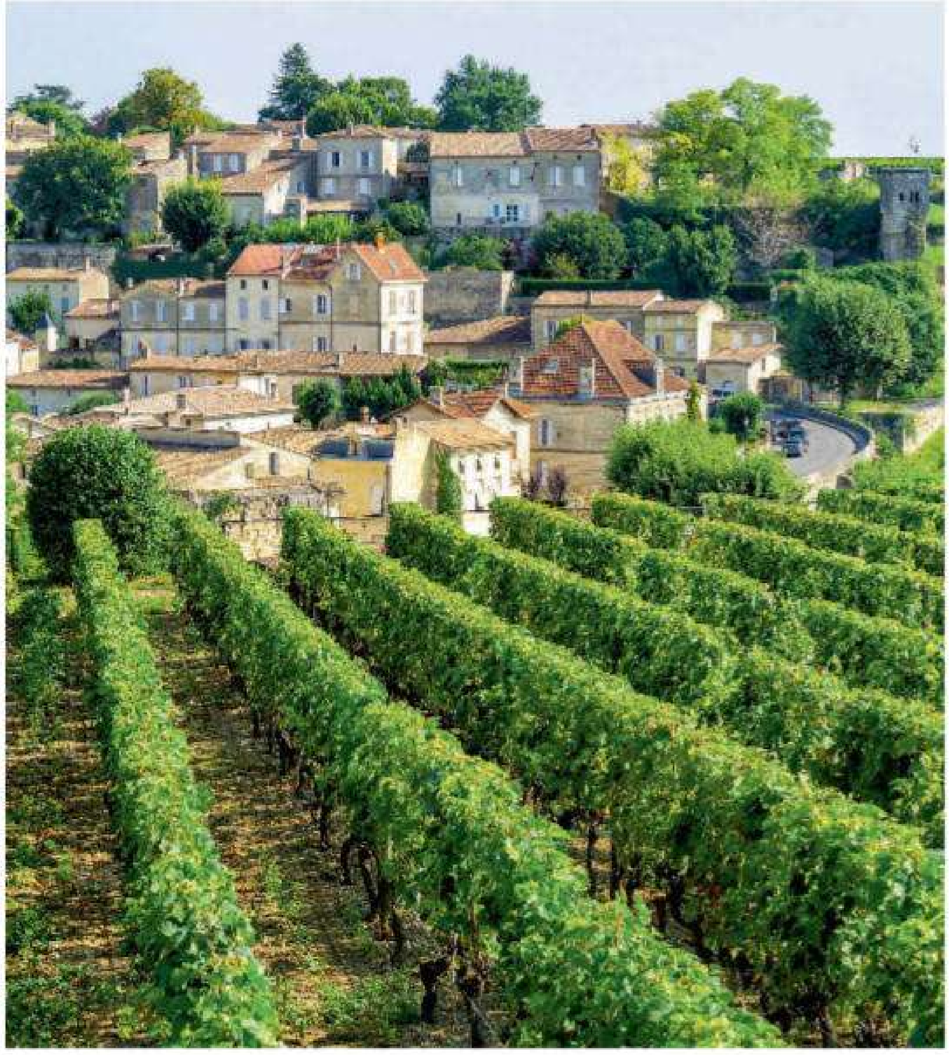
Brian Wood at the University of California, Los Angeles, and Claire Spottiswoode at the University of Cape Town, South Africa, found that in Tanzania, honeyguides respond to 81 per cent of the whistles local Hadza honey-hunters use to call them, but to just 24 per cent of the trill-grunts used by Yao honey-hunters from Mozambique. Swap countries, and the situation is reversed (*Science*, doi.org/k73f). This shows the birds learn the specific signals used by local hunters. **Ryan Truscott**

Biology

Strange fungi look like *Dune* worms

FOUR previously unknown species of sand-dwelling fungi have been described in Hungary. They are stalked puffballs, which have a round, spore-spewing fruiting body on a pillar.

Bálint Dima at Eötvös Loránd University in Hungary and his colleagues collected specimens from sandy grasslands with dunes by the Danube river. They say four of the species are new to science: *Tulostoma dunense*, *Tulostoma hungaricum*, *Tulostoma sacchariolens* and *Tulostoma shaihuludii* (*MycoKeys*, doi.org/k732). The last of these was named after the Shai-Hulud, the giant sandworms from Frank Herbert's *Dune* science fiction novels. *T. shaihuludii* has a curved stalk, so the puffball cap faces sideways, evoking a sandworm emerging from the desert, says Dima. **Jake Buehler**



LARASLK/SHUTTERSTOCK

Chemistry

AI can tell which chateau Bordeaux wines are from

WINES really are given a distinct identity by the place where their grapes are grown and the wine is made, according to an analysis of red Bordeaux wines.

Alexandre Pouget at the University of Geneva, Switzerland, and his colleagues used machine learning to analyse the chemical composition of 80 red wines from 12 years between 1990 and 2007. All were from seven wine estates in the Bordeaux region of France.

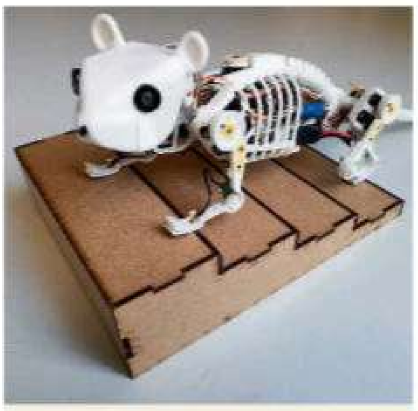
"We were interested in finding out whether there is a chemical signature that is specific to each of those chateaux," says Pouget, meaning one estate's wines would have a very similar chemical profile, and therefore taste, year after year.

To do this, the researchers vaporised each wine and separated it into its chemical components. This gave them a readout for each wine, called a chromatogram, with about 30,000 points representing different chemical compounds.

The researchers used 73 of the chromatograms to train a machine learning algorithm, along with data on the chateaux of origin and the year. Then they tested the algorithm on the seven chromatograms that had been held back. They repeated the process 50 times, changing the wines used each time. The algorithm correctly guessed the chateau of origin 100 per cent of the time. "Not that many people in the world will be able to do this," says Pouget. It was also about 50 per cent accurate at guessing which year the wine was made in (*Communications Chemistry*, doi.org/k73v).

The work is more evidence that local geography, climate, microbes and wine-making practices, together known as terroir, give wine a unique flavour. **Chris Simms**

Really brief



ZHENSHAN BING/TUM/GERMANY

Flexi-spine makes robot mouse agile

A mouse-like robot with an articulated spine is faster, more agile and defter at balancing than rigid competitors. The machine is about 40 centimetres long and weighs 225 grams (*Science Robotics*, doi.org/gs78bp). Such flexibility may help robots wiggle and squeeze through tiny gaps.

The best way to grind coffee beans

Adding a drop of water to your coffee beans before grinding them can reduce mess and lead to a more flavourful brew. Pouring in about half a millilitre to a typical brew should stop the grounds clumping together and improve the consistency and flavour of an espresso (*Matter*, doi.org/gs75xz).

Spinning gives locusts a hard case

Locusts placed in a centrifuge to mimic the conditions of hypergravity grew tougher legs than those living normally. The results may help us to work out how biological materials evolve under stress and to design materials that can naturally adapt (*Proceedings of the Royal Society B*, doi.org/gs756k).

Welcome to New *Scientist*'s rundown of the biggest science and technology stories this year

Record heat
Why 2023 was probably the hottest year we have ever seen this page >

Superconductor scramble
A claimed wonder material sent social media into overdrive p18

Lingering illness
Covid-19 no longer led the headlines, but still remained a concern p19

Terrific tile
Mathematicians discovered a shape like no other p20

Lunar glory
India became the fourth nation to land successfully on the moon p20

Wegovy demand
Weight-loss drugs took off, but faced supply shortages p21

AI revolution
It has been impossible to escape the success of artificial intelligence p22

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Why the condition's rise in younger people remained a mystery p23

Eyes in the sky
Chinese spy balloon saga highlighted surveillance threats p23

Wonders of the universe
The best space pictures, from a solar tornado to green comets p24

Climate change

Extreme heat like we've never seen before

Greenhouse gas levels and the arrival of El Niño pushed the world's climate into "uncharted territory" in 2023

James Dinneen

THE official numbers aren't in yet, but this past year was almost certainly the hottest on record, with high temperatures driving extreme events across the planet. From record-breaking wildfires in Canada to record-low levels of sea ice in Antarctica, researchers say this year's weather phenomena were shocking, even if they were precisely what was anticipated with climate change.

"We're getting to a point where one year was bound to happen where [the effects of climate change] would be so pervasive we started to pay attention," says Pedro DiNezio at the University of Colorado Boulder. "Maybe it was 2023."

The first intimations that this year would be one for the record books began with forecasts in late 2022 that the Pacific Ocean would see a shift to a warmer El Niño climate pattern the following year. This came after three years of a cold La Niña pattern that had masked the effect of steadily rising concentrations of greenhouse gases in the atmosphere, says Michael McPhaden at the US National Oceanic and Atmospheric Administration (NOAA). "During La Niñas, the ocean takes up more heat than usual," he says. "During El Niño, that heat is released back into the atmosphere."

The results of this shift started to become clear in June, when global average temperatures first began setting records. Some regions, such as parts of the North Atlantic Ocean, saw unprecedented temperatures, as warming due to rising greenhouse gases exacerbated heat driven by natural variability in the climate system. June also saw heat and dry weather intensify wildfires burning in Canada. These went on to smash records for the area burned and carbon emitted, and sent suffocating smoke across the densely populated US east coast.

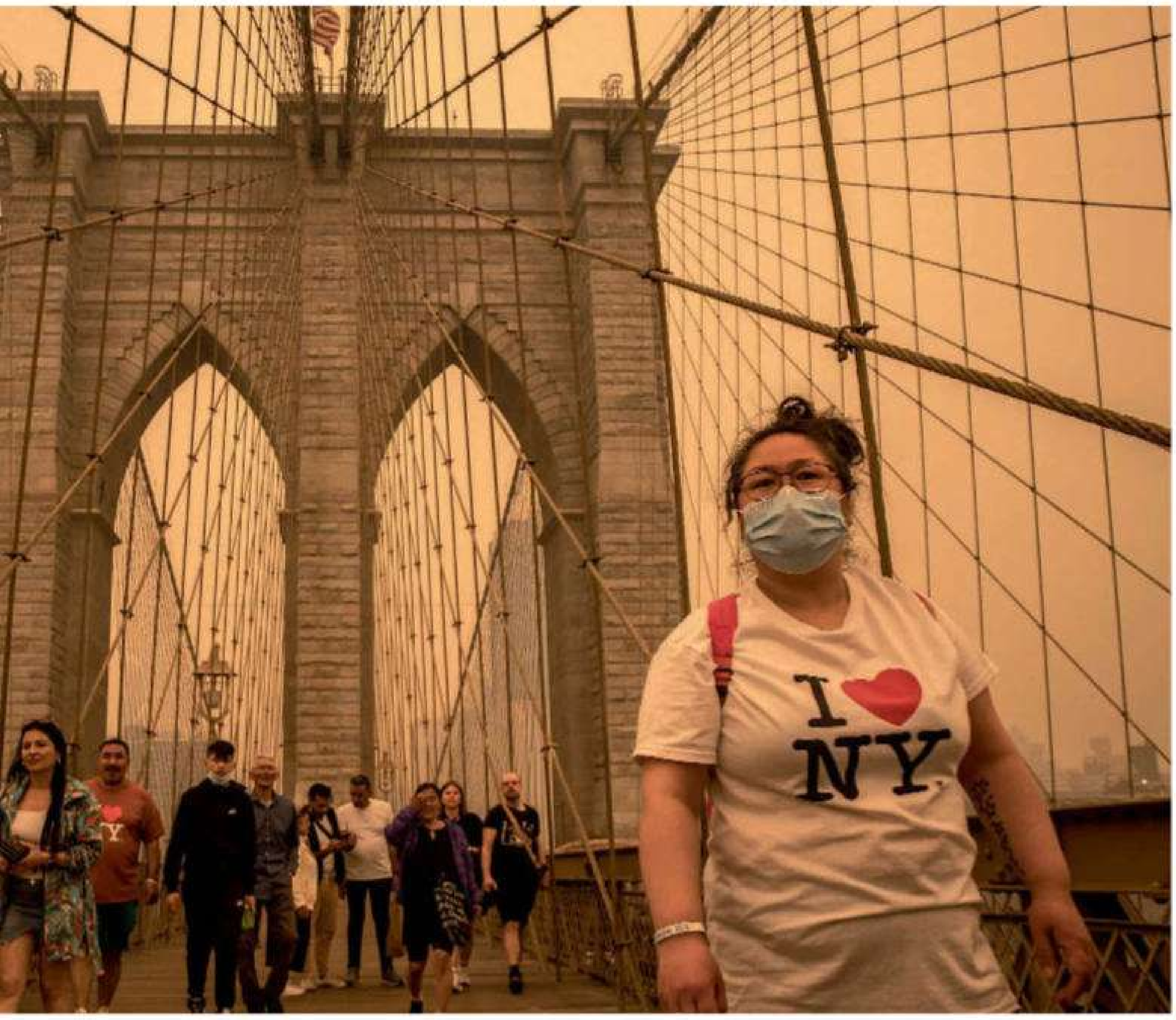
Briefly the hottest month on record, June was soon supplanted by July, which saw things hot up even more. A wobbly pattern in the jet stream continued to drive simultaneous heat waves on three continents. To take one scorching example, Phoenix, Arizona, suffered nearly the entire month with temperatures above 43°C (110°F). The global average temperature for July was more than 1.5°C above the pre-industrial average – the first month in which this has happened during the northern hemisphere summer. Researchers found that these temperatures would have been virtually impossible without climate change.

Record highs

The hot streak continued in the following month, which was the hottest August on record. One of the most striking events was in South America, where parts of Chile and Argentina saw what was effectively a heatwave in the middle of winter. Another alarming indicator between June and August – which was the hottest three-month stretch on record – was in Antarctica, where sea ice failed to recover during the southern winter from record low levels set earlier in the year.

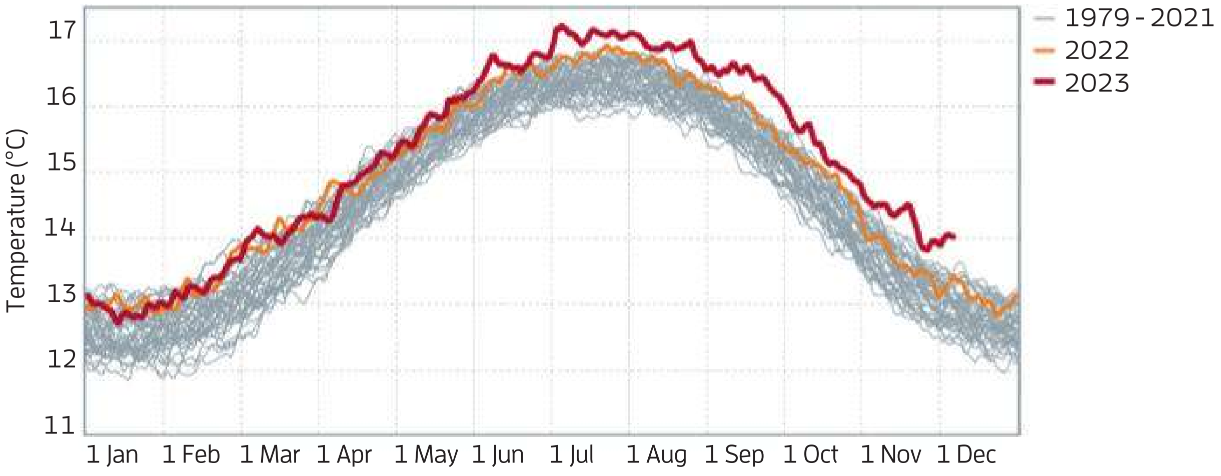
Top: New York is shrouded in wildfire smoke in June. Smaller images, left to right: a wildfire in Greece in August; the low water level in Lake Titicaca, Bolivia; workers fix insulating foam on the Rhone glacier in Switzerland

Climate summit latest
For all the news from COP28 visit
newscientist.com/cop28



CLOCKWISE FROM TOP: NYT/REDUX/EYEVINE; FABRICE COFFRINI/AFP VIA GETTY; GASTON BRITO MISEROCCHI/GETTY; AYHAN MEHMET/ANADOLU AGENCY VIA GETTY

Average global air temperature



NCEP CFSV2/CFSR | CLIMATEREANALYZER.ORG, CLIMATE CHANGE INSTITUTE, UNIVERSITY OF MAINE (17°C=63°F)

The extraordinary heat didn't let up with the seasons. September, though not as hot as the preceding months, saw the largest difference when compared with historical temperatures on record, rising to around 1.8°C above the pre-industrial average – a huge jump from any previous year. Zeke Hausfather at Berkeley Earth memorably called the size of this anomaly "gobsmackingly bananas".

That put to rest nearly all doubt that 2023 would end up the hottest year on record, replacing the previous record year in 2016, which, not incidentally, also saw a strong El Niño develop in the Pacific. In its end of September climate report, NOAA had the odds at 99 per cent that 2023 would be the hottest year on record. An official determination will be made in January.

"The truth is that we are shocked by the ferocity of the extreme weather events in 2023," William Ripple at Oregon State University and his colleagues wrote in an end-of-year report on the state of the climate. "We are afraid of the uncharted territory that we have now entered."

Between January and the end of September, the global average surface temperature was 1.1°C above the pre-industrial average, according to NOAA. That is 0.03°C above the previous record for that period from 2016. But this record may not stand for long. As El Niño reaches its peak strength early next year, McPhaden says it isn't unreasonable to expect 2024 to be even hotter. "We're on an escalator that's only going one way. And that's up." ▮

Materials

The viral superconductor

A claimed breakthrough substance called LK-99 became an unlikely social media star

Karmela Padavic-Callaghan

IT IS rare for materials science to make headlines, and practically unheard of for it to become a viral success. But in July this year, that is exactly what happened when a group of researchers claimed to have created a superconducting material that operates at room temperature and ambient pressure. While the claims probably don't hold up, the tale of a material called LK-99 showed a new way of doing science. Forget peer review – this was meme review.

Two papers authored by members of the Quantum Energy Research Centre in South Korea and published on the arXiv preprint server ordinarily would have gone unnoticed by most people. While superconductors have long held the promise to revolutionise the way we use electricity, the past century has seen failed attempt after failed attempt at making them work at anything other than extremely low temperatures and high pressures. As such, LK-99 was met with scepticism from experts.

It was a post on X (at the time, Twitter) eventually seen by over 30 million people that turned the material from a would-be superconductor into a would-be superstar: "Today might have seen the biggest physics discovery of my lifetime," wrote user Alex Kaplan, who works at a Massachusetts coffee firm, before going on to describe some of the sci-fi advances that could be made possible by such a material.

As LK-99's popularity rose, professional scientists who might otherwise have stayed silent felt the need to react. Prashant Jain at the University of Illinois at Urbana-Champaign says that researchers conducted experimental and theoretical studies impressively quickly and shared their insights in a measured and accessible way after interest in LK-99 skyrocketed.

Within days, social media was overflowing with theories and details about LK-99, as well as updates on efforts to synthesise it and test its properties in laboratories and even a few at-home set-ups. "It almost became a meme," says Christopher Hendon at the University of Oregon.

Some of the most debated evidence around LK-99 was videos that showed chunks of the material partially levitating above magnets, seemingly exhibiting a signature of superconductivity called the Meissner effect. By following the recipe for LK-99 laid out in the research papers, amateurs were able to create the material and film similar videos, fuelling the online excitement.

But after a few weeks, almost a dozen experiments had failed to reproduce any of the other hallmarks of superconductivity originally reported, and many observations were revealed to be less exotic effects stemming from other compounds present in LK-99 samples, like copper sulphide.

> "PEOPLE WERE ABLE TO FIGURE OUT WHAT WAS ACTUALLY GOING ON IN A VERY SHORT TIME"

A sample of LK-99, which displayed unusual magnetic properties

Now that the dust has settled, all the researchers who spoke to *New Scientist* agree that it is unlikely that LK-99 is any sort of miracle material. "The method of synthesis is clear, and it is possible to synthesise the material, but we could not see any signatures of superconductivity yet," says V. P. S. Awana at the National Physical Laboratory of India.

But equally, all of the scientists expressed the sentiment that, for a few weeks in 2023, LK-99 exposed the scientific process, and the nitty-gritty of what it takes to do materials science well, to millions who had never seen it so up close and personal before.

"The fact that people did attempt to replicate and were able to figure out, in a very short amount of time, what was actually going on, is an example of how science works," says Inna Vishik at the University of California, Davis. What was unusual was the speed. "It's very rare that science works in two weeks." ▮

ROKAS TENYS/ALAMY

Coronavirus

Covid-19 crisis phase ended but virus still lingers

Grace Wade

WHEN it comes to covid-19, 2023 was different to the pandemic's previous three years. Across the globe, hospitalisations and deaths reached all-time lows. On 5 May, the World Health Organization (WHO) announced the virus was no longer a public health emergency, suggesting the pandemic's crisis phase had ended.

"It is a really important inflection point of accomplishment," says Maria Van Kerkhove at the WHO. "But that's not the end of the story. While the crisis is over, the virus is still with us."

SARS-CoV-2, the coronavirus behind covid-19, emerged in China towards the end of 2019. Since then, around 7 million deaths have been reported worldwide, of which fewer than 4 per cent occurred in 2023. And while tens of thousands of people died from covid-19 each week between 2020 and 2022, the weekly reported death rate for most of 2023 was well below 10,000 globally.

Hospitalisations and deaths, the two most accurate metrics for gauging an outbreak's severity, have really diminished, says William Schaffner at Vanderbilt University in Tennessee. This is largely due to most people having some form of immunity against the virus, he says. For instance, it is estimated that more than 90 per cent of people in the US and the UK have antibodies against covid-19. "This indicates that the virus is now becoming endemic, meaning it circulates at lower levels in the population with occasional outbreaks," says Schaffner.

Some experts have suggested covid-19's risk is now on a par with that of seasonal flu. Yet there are considerable differences between these viruses. Most notably, covid-19 is still rapidly evolving. "We don't have one variant that is dominant worldwide, so there's an unpredictability about what's next," says Kerkhove. Early in 2023, a variant called XBB.1.5 dominated due to its improved ability to infect human cells. It was then overtaken by the even more transmissible EG.5.

Nirav Shah at the US Centers for Disease Control and Prevention says emergency responses should be in place for both covid-19 and flu. "We should start treating them more akin to one another." One of these responses should be regularly updating vaccines to better protect people against circulating variants, which has long been in place to control flu. In September, new covid-19 booster vaccines became available in countries such as the US, the UK, France and Canada, targeting XBB.1.5 instead of the ancestral strain.

But not everyone who wants the vaccine has been able to get it. Issues with roll-outs have hindered availability in the US and only individuals at high risk of covid-19, such as older adults and healthcare workers, can get it in the UK and other European countries.

While the threat of covid-19 diminished considerably in 2023, its risk is still far from insignificant. Before the pandemic, there were two main respiratory viruses circulating, respiratory syncytial virus (RSV) and flu. The addition of covid-19 means hospitalisations will continue to be higher than they once were, straining healthcare systems, says Shah. Four years in, we also still have much to learn about the virus, particularly when it comes to long covid and the risk of repeat infections, says Kerkhove. "We still have to be vigilant. We still have to maintain our work to deal with covid, but to deal with it in the context of everything else." ▮

<4%

Proportion of covid-19 deaths that took place in 2023

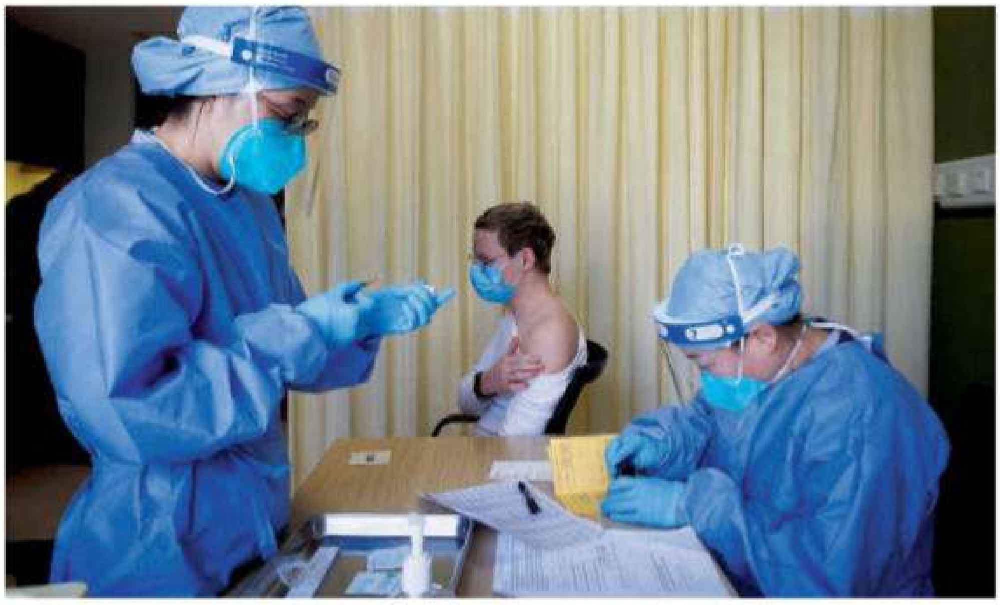
>90%

Proportion of people in US and UK with antibodies against covid-19

EG.5

The highly transmissble variant that became dominant in 2023

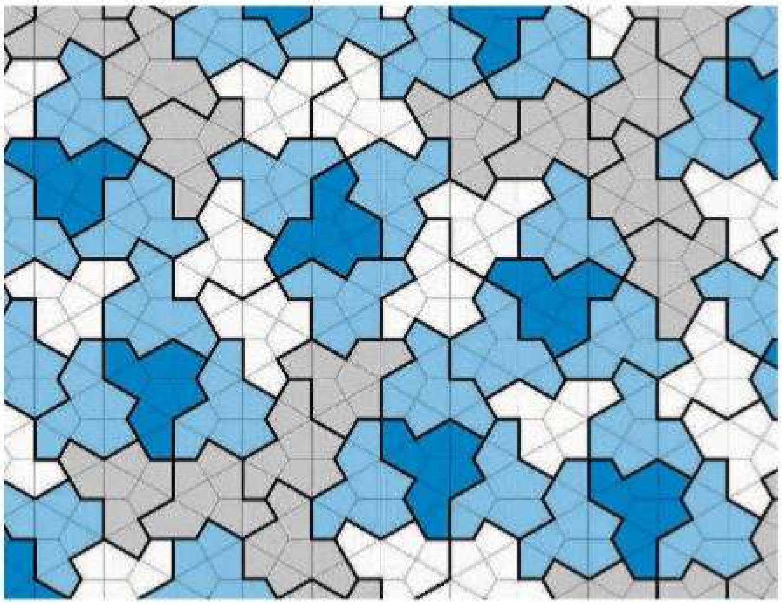
A covid-19 vaccine being prepared in Beijing in January


REUTERS/THOMAS PETER

Mathematics

The ultimate bathroom tile had mathematicians celebrating

Matthew Sparkes



CRAIG S. KAPLAN

The "hat" shape can tile an infinite plane without creating repeating patterns

IT IS rare for a shape to make a splash, but this year one did just that with the announcement of the first ever single tile that can cover a surface without forming repeating patterns. The discovery of this "aperiodic monotile" in March has since inspired everything from jigsaw puzzles to serious research papers.

"It's more than I can keep up with in terms of the amount and even, to some extent, the level and depth of the material, because I'm not really a practising mathematician, I'm more of a computer scientist," says Craig Kaplan at the University of Waterloo, Canada. He is on the team that found the shape, which it called the "hat". Mathematicians had sought such an object for decades.

After revealing the tile in March, the team unveiled a second shape in May, the "spectre", which improved on the hat by not requiring its mirror image to tile fully, making it more useful for real surfaces.

The hat has since appeared on T-shirts, badges, bags and as cutters that allow you to make your own ceramic versions.

It has also sparked more than a dozen papers in fields from engineering to chemistry. Researchers have investigated how the structure maps into six-dimensional spaces and the likely physical properties of a material with hat-shaped crystals. Others have found that structures built with repeating hat shapes could be more resistant to fracturing than a honeycomb pattern, which is renowned for its strength.

Kaplan says a scientific instrument company has also expressed an interest in using a mesh with hat-shaped gaps to collect atmospheric samples on Mars, as it believes that the pattern may be less susceptible to problems than squares.

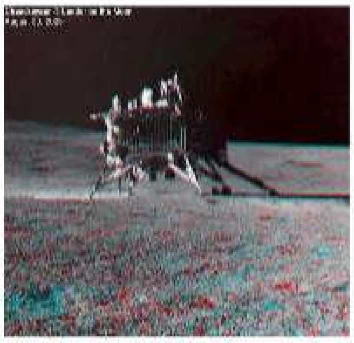
"It's a bit bittersweet," says Kaplan. "We've set these ideas free into the world and they've taken off, which is wonderful, but leaves me a little bit melancholy because it's not mine any more."

However, the team has no desire to commercialise the hat, he says. "The four of us agreed early on that we'd much rather let this be free and see what wonderful things people do with it, rather than trying to protect it in any way. Patents are something that, as mathematicians, we find distasteful." ▮

Space

India made history with low-budget moon landing

Matthew Sparkes



People in New Delhi, India (right), cheer as the Vikram lander (left) touches down

IN AUGUST, India achieved what only the US, the USSR and China had done before and successfully landed a craft on the moon.

The Indian Space Research Organisation's Vikram lander and Pragyan rover carried out a string of scientific experiments that will shed light on the composition of the moon's surface, and the former performed a short take-off and repositioning to give engineers insight for future missions.

Around two weeks after the Chandrayaan-3 mission began – a single period of lunar daylight – both devices went into "sleep mode" and prepared for temperatures to plunge as low as -238°C, which would be very likely to destroy electronic components. While there were tentative hopes that the rover could reawaken for another day's exploration, that didn't happen.

Sarah Casewell at the University of Leicester, UK, says the chances of reviving the lander or rover now are extremely slim, as they have passed through several lunar nights, but this takes nothing away from the mission's "phenomenal achievement".

Chandrayaan-3 should be considered a success by any measure, she says, but given its budget of just £60 million ($74 million), it also represents a triumph of careful planning. ▮

L: ISRO; R: SANCHIT KHANNA/HINDUSTAN TIMES VIA GETTY IMAGES

DPA PICTURE ALLIANCE/ALAMY

Wegovy shortages have seen "off label" use of the diabetes drug Ozempic

Medicine

Obesity revolution

Demand for the drugs Wegovy and Ozempic led to restrictions on use and dangerous counterfeits

Clare Wilson

WEIGHT management was transformed in 2023, with soaring use of the drug Wegovy, or semaglutide. Never before has there been an approved weight loss medicine that is so effective and yet also considered reasonably safe. "The medical therapy of obesity has been revolutionised," says Daniel Drucker at the University of Toronto, Canada.

Amid near constant media coverage, demand for Wegovy rose so much that supplies in some pharmacies ran out in the US, where the drug was launched in 2021. This led to knock-on shortages of Ozempic, the version of semaglutide used to treat type 2 diabetes.

Semaglutide mimics the actions of a hormone called GLP-1, which is normally released after eating. This has several effects on the body, including cutting appetite and triggering the release of the hormone insulin, which regulates blood sugar.

GLP-1 mimics were developed to treat type 2 diabetes, but their effects on appetite meant they were then approved as weight loss treatments for people without diabetes. In fact, these medicines cause even more weight loss in people without diabetes, by as much as 15 per cent.

Following Wegovy's US launch, the drug's Danish manufacturer Novo Nordisk couldn't keep up with demand and repeatedly delayed its other launches, but it has since been made available in some European countries, such as the UK. Novo Nordisk's obesity medicine sales rose by about 160 per cent between January and June this year, primarily driven by Wegovy sales in the US. The firm had to limit supplies of the lower starting dose of Wegovy in that country to help those who had reached the higher maintenance dose continue treatment without interruption, as when people stop taking the medicine, weight slowly but inexorably returns.

In many countries, people who want semaglutide for weight loss have resorted to taking Ozempic, as doctors may prescribe this "off label" even for people without diabetes. The end result is that those seeking semaglutide may have to call round multiple pharmacies to find stock. "It is stressful for people to have to spend so much time and effort to get the medicine they need," says Drucker.

Some nations, such as the UK, have brought in export bans for semaglutide-based drugs. The state of British Columbia in Canada has introduced stricter rules about people needing to have a diabetes diagnosis before they can get Ozempic.

One option for increasing supply is to switch people to other GLP-1 mimics that work in a similar way, such as liraglutide (Saxenda), but these are somewhat less potent for weight loss, so are being used at higher doses, says Drucker.

People are even resorting to buying the GLP-1 mimics from illegal sources online, with dangerous results. The UK's Medicines and Healthcare Products Regulatory Agency warned in October that some people had ended up in a coma after using counterfeit versions of Ozempic injection pens. The fakes seem to have been insulin injection pens given new labels, as some of the users had gone into a coma due to plunging blood sugar levels.

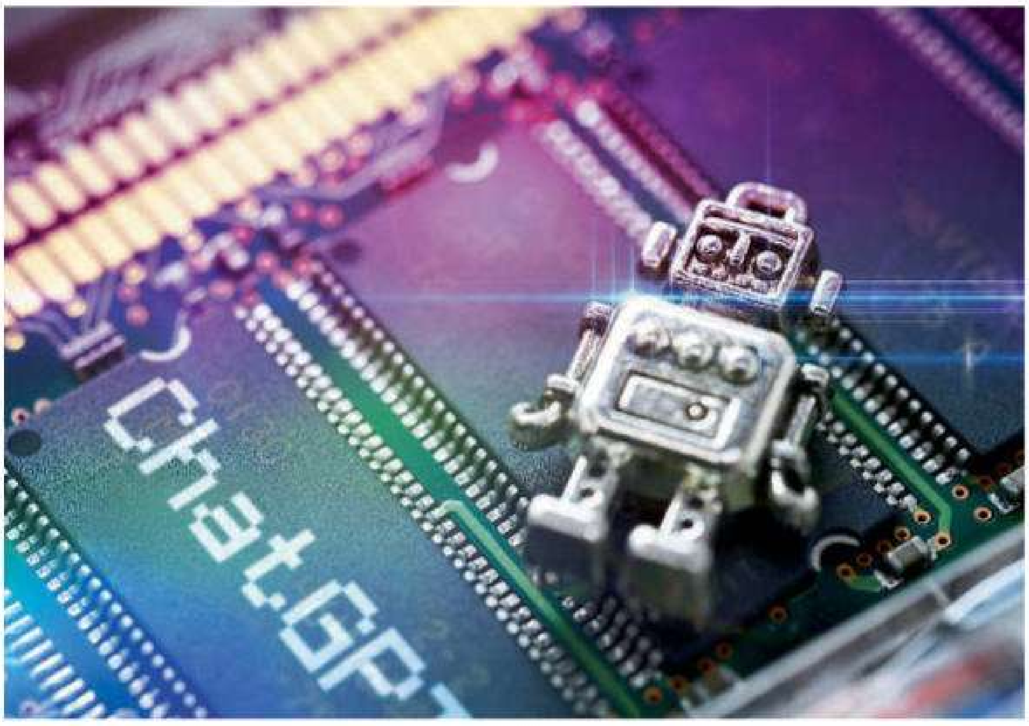
All of this demonstrates the incredible desire for solutions to obesity. Mike Lean at the University of Glasgow, UK, says the demand for a new drug outstripping supply so much has happened only a few times previously, such as when anti-HIV drugs came out in the 1990s. "This has almost never happened before," he says. ▮

Technology

Clever chatbots launched AI boom

Highly versatile large language models have taken the world by storm

Alex Wilkins



ChatGPT emerged as the front-runner among a wave of AIs with wide-ranging abilities

L: BILDAGENTUR-ONLINE/OHDE/ALAMY; R: AP PHOTO/PATRICK SEMANSKY/ALAMY

IT WAS hard to avoid artificial intelligence in 2023, with the vertiginous rise of chatbots powered by large language models (LLMs). By February, OpenAI's ChatGPT had become the fastest-growing app of all time. By the year's end, it had become an everything machine: browsing the internet, interpreting pictures, generating any requested image and inserting itself into many existing tools and services – and it wasn't the only AI to do so.

"Where the technology is going next is clearly to be more multimodal," says Michael Wooldridge at the University of Oxford. "It will be to do with sound and voice and video and so on."

Sleeping giants like Google and Microsoft were jolted awake by OpenAI's success. Microsoft, which is a large investor in OpenAI, has incorporated GPT-4, the latest LLM to power ChatGPT, into its search engine Bing and programs such as Word and Excel. Google released its Bard chatbot in February and, in December, unveiled Gemini, its most powerful LLM yet, which it claimed can exceed GPT-4's capabilities on a range of tasks.

These AIs have now become part of daily life for a large chunk of the population, from students looking for help with homework to software developers. With the introduction of GPT-4 in March, ChatGPT became even more capable at generating responses. Some observers claimed it showed the first sparks of artificial general intelligence – the ability to understand and learn any intellectual task that humans are capable of – though many people disagreed.

OpenAI's triumphant year almost came off the rails in November, when its board unexpectedly fired CEO Sam Altman. The vast majority of its staff threatened to quit en masse, and he was quickly reinstated (see page 27).

> "EVERYBODY WANTS TO BE THE EMPIRE THAT'S BUILT ON THE BACK OF THIS TECHNOLOGY"

Sam Altman, CEO of OpenAI, was fired this year but quickly reinstated

AI's renaissance in 2023 has been a seismic technological event, says Wooldridge. "Everybody wants to be the empire that's built on the back of this technology, and what we're seeing is a frenzy from big tech companies."

Some economists have estimated that millions of jobs could be at risk from automation, but much is still unclear. We don't know how capable these models are, and legal questions remain around how they are trained.

In the US, there are at least seven copyright infringement lawsuits against AI companies. A group of programmers suing Microsoft for its code-generating Copilot program were the first to take action, and large corporations like Getty Images soon followed, suing Stability AI for allegedly using copyrighted images to train its Stable Diffusion image generator.

Though many people suspect that their online data has been scraped and used to train these models, it is hard to prove because the datasets and training methods have been kept secret, supposedly to protect commercial secrets.

AI's leap forward also caught the attention of national governments, who see the tech as both a threat and an opportunity. In November, the UK hosted a summit where 28 countries and the European Union signed a declaration agreeing that global action is needed to minimise the risks of AI. At the same time, US president Joe Biden signed an executive order requiring companies training AI models of a certain size to comply with government safety and national security procedures. The EU is also working on its own AI law aiming to regulate the largest models, which is expected to come into effect in 2025. ■

Health

Rise of cancer in younger people sparked concern

Clare Wilson

RESEARCHERS called this year for an urgent need to understand the rising rates of cancer in people under the age of 50, saying we must finally get to grips with this growing problem.

Over the past few decades, the number of diagnoses for those early-onset cases – so-called because most tumours are diagnosed in people over 50 – has been rising in multiple cancer types, including those of the breast and prostate.

50%

The rise in cases of early-onset bowel cancer in several countries

This trend has been most marked for cases of bowel cancer, with about a 50 per cent rise in the rate of people aged 25 to 49 being diagnosed with the condition since the 1990s in the US, Canada, Australia and many European countries.

The explanation doesn't seem to be wider screening, as this is mostly offered to people older than 50. Instead, proposed causes include changes to diet, sleep patterns, antibiotic use, stress, exercise levels, environmental contaminants or the microbiome.

Now, there is an increased focus on the problem, since an announcement in March by the US National Cancer Institute (NCI) and Cancer Research UK (CRUK) that understanding early-onset cancer is one of their nine new "grand challenges".

The cause is probably some aspect of affluent modern life, says Shuji Ogino at Harvard Medical School. That is because the rate of early-onset cancers is rising progressively for people born in the 1950s, 1960s, 1970s and so on. "The evidence suggests each birth cohort has a higher risk at a given age," says Ogino.

This coincides with a rise in wealth after the second world war. "In the 1940s, only a limited number of people had a wealthy lifestyle, with a car and eating as much as they want. Later on, more and more people had access to that lifestyle."

The NCI and CRUK have asked for scientists to submit grant applications for research that investigates trends in the "exposome" – everything people are exposed to in the environment, such as contaminants and their lifestyle, that could influence their risk of developing medical conditions. They will announce who has been successful in March 2024.

Despite the trend of rising cancer diagnoses in younger people, most cases are still diagnosed in those aged 50 or older, so the shift hasn't yet had much effect on total cancer incidence. Nevertheless, it shows no signs of stopping. "This is a big challenge," says Ogino.

Changing diets may be one explanation for a rise in early-onset cancer

COLDSNOWSTORM/GETTY IMAGES

Aeronautics

Spy balloon saga inflated US-China political tensions

Jeremy Hsu

PICTORIAL PRESS LTD/ALAMY

ONE of the year's most unexpected controversies involved a US fighter jet shooting down a huge Chinese balloon that drifted across the US and Canada in January and February. The incident prompted the postponement of a high-profile US diplomatic visit to China and put the North American Aerospace Defense Command on high alert.

After the wreckage was recovered from the sea, the US government described the balloon as having carried surveillance equipment – something Chinese officials denied – but also acknowledged that it didn't seem to have collected or sent any data.

"The balloon still posed a potential national security threat because it had the surveillance capabilities to collect information," says Timothy Heath at the RAND Corporation, a think tank in California. "Whether China intended to use the balloon to spy on the USA is less clear now."

US fighter jets subsequently shot down three smaller flying objects of unknown origin, some cylindrical, that were possibly airborne debris, but almost certainly not aliens. That led US President Joe Biden to say he would boost the country's capabilities for tracking similar objects. Such measures may include increasing radar sensitivity and creating databases to catalogue unidentified flying objects, says Heath.

But "the threat posed by balloons should not be overstated" in comparison with surveillance satellites and drones, he says.

Astronomy

The year's best space images

Stargazers and space telescopes stunned us with a wealth of wonders

Leah Crane

THE James Webb Space Telescope (JWST) has helped make 2023 a year of astonishing cosmic images. But the groundbreaking telescope was far from the only source of visual wonderment, because a series of new missions sent back pictures from space (including India's Chandrayaan-3 project, see page 20), and the view from Earth wasn't bad either. Here are four of the images that dazzled us the most.

The star in the main picture, right, was caught by JWST getting ready to explode. It is called WR 124 and is about 30 times the mass of the sun.

When stars that big run out of hydrogen to burn in their core, they begin to fuse heavier elements instead. This fusion creates powerful blasts of energy, blowing out gusts of wind at velocities in the millions of kilometres per hour. When those powerful winds strip away the outer layers of the star, it becomes what is known as a Wolf-Rayet star.

Within a few million years of being stripped, it blows up in a supernova. The purplish blotches in this picture are the clouds of dust and gas that used to be WR 124's outer layers – it has already lost about 10 times the mass of the sun – and without those layers intact, it is now doomed to go supernova.

Next up, we have the tallest solar tornado ever recorded (bottom row, near right). The event occurred on 14 March, when the rotation of the sun's magnetic fields churned up the plasma near its north pole. This feature rose from the sun's surface until the giant flare reached 178,000 kilometres tall – that is nearly 14 times the diameter of Earth.

This image was the result of a painstaking collaboration between astrophotographers Jason Guenzel and Andrew McCarthy. They used a high-speed camera to record the event, and took five days and 90,000 individual shots to create their picture. The sun looks furry in the image because it is covered in millions of churning geysers of plasma that last only a few minutes each.

The image to the right of the seething sun reveals a newborn star's incredible supersonic jets. These make it what is known as a Herbig-Haro object. The star itself is hidden in the dark cloud of gas from which it formed, but as the jets shoot out on either side of it, they slam into surrounding gas and dust, creating huge shock waves and lighting up.

This particular object, called Herbig-Haro 211, is about 1000 light years from Earth in the constellation Perseus. That makes it one of the nearest Herbig-Haro objects we know of, which is why JWST was able to capture the most detailed image of one ever taken. This revealed strange wiggles in the jets, which may indicate that Herbig-Haro 211 actually has a companion star.

Our final image (bottom row, far right) shows the comet Nishimura, seen from Earth as it streaked across the night sky.

Two rare green comets made dramatic appearances in the skies this year. First, in early February, the comet C/2022 E3 made its first close pass to Earth in 50,000 years. Then, in August, amateur astronomer Hideo Nishimura discovered another comet – now named after him – which remained visible for about two months. These comets appear green because the gas around their rocky nuclei contains diatomic carbon, which is a relatively rare substance made of pairs of bound carbon atoms.

Make the most of the image of Nishimura now because the comet takes about 437 years to orbit the sun, so won't be seen again until the 25th century. ▮

Right: Wolf-Rayet star WR 124 as glimpsed by JWST

Bottom left: A solar tornado seen from Earth

Bottom middle: Newborn star Herbig-Haro 211, captured by JWST

Bottom right: An amateur astronomer's view of comet Nishimura

178k

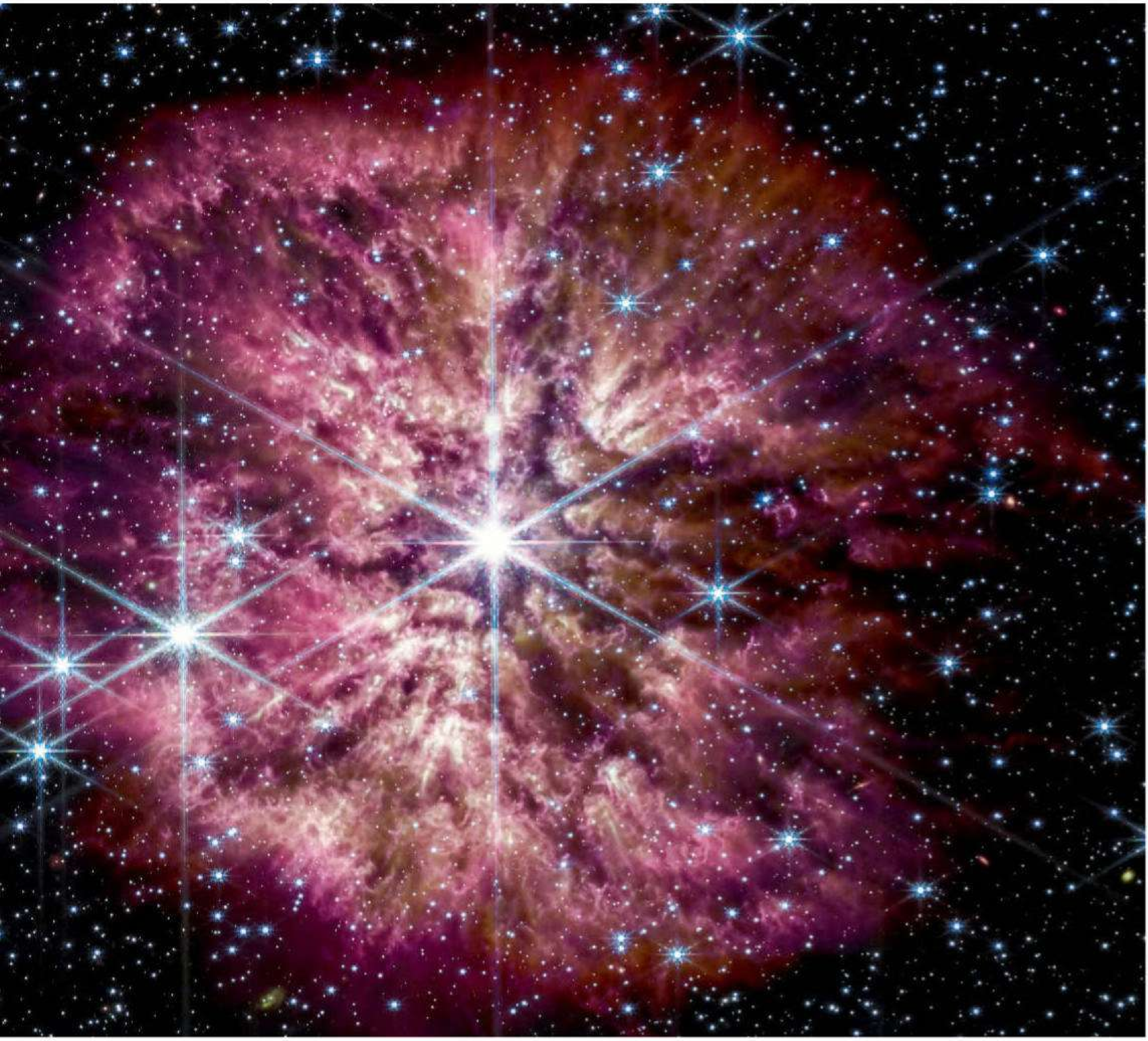
The height of the solar flare (near right) in kilometres

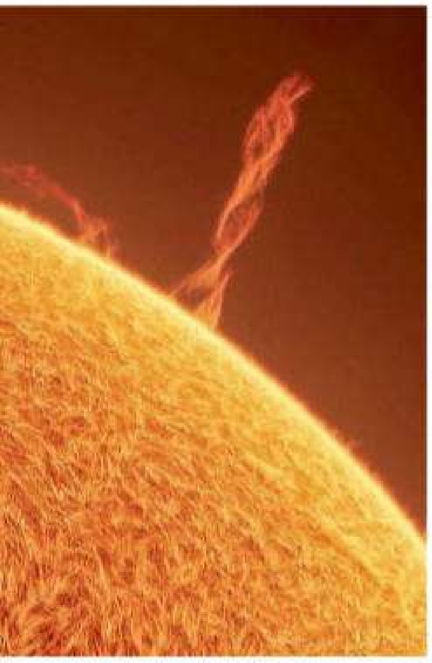
1000

Distance in light years to Herbig-Haro 211 (centre right)

437

Number of years comet Nishimura (far right) takes to orbit the sun





CLOCKWISE FROM TOP: NASA, ESA, CSA, STSCI AND ERO PRODUCTION TEAM; JAVIER ZAYAS/MOMENT RF/GETTY IMAGES; ESA/WEBB, NASA, CSA, TOM RAY (DUBLIN); ANDREW MCCARTHY AND JASON GUENZEL

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Column

Looking back at 2023

New Scientist's columnists look back at effective altruism, the state of the environment, a new human story and the hunt for universal truths

This changes everything

Annalee Newitz on a tale of two Sams

SIMONE ROTELLA

THIS was the year when two of Silicon Valley's biggest hype blimps – cryptocurrency and artificial intelligence – were deflated by drama. First came the downfall of Sam Bankman-Fried, whose shady cryptocurrency empire landed him in court, where he was convicted of fraud and conspiracy. During his trial, witnesses and evidence revealed that Bankman-Fried's cryptocurrency exchange FTX was siphoning billions of dollars from unwitting investors into one of his other assets, a cryptocurrency trading firm called Alameda Research.

A few weeks later, the other Silicon Valley Sam – Sam Altman – went through a corporate melodrama. Altman is CEO of OpenAI, maker of ChatGPT and one of the world's most successful AI start-ups. In late November, the board of OpenAI claimed, rather mysteriously, that Altman wasn't "consistently candid" with it and abruptly fired him. Stung, Altman hastily arranged a deal to set up his own research division at Microsoft.

When most of OpenAI's 700+ employees threatened to defect with Altman to Microsoft, he was reinstated at OpenAI and the board was overhauled. There is still no official story about why it all happened, but let's just say Altman had a really bad week where he almost lost his billion-dollar baby.

Aside from their first names and billionaire drama, they have nothing in common – other than their association with a fashionable form of philanthropy known as effective altruism (EA).

Popularised by the philosopher William MacAskill, EA has many adherents in Silicon Valley. They love its directive of "earn to give", which suggests that people should rake in as much money as possible in order to donate a portion of it to "optimal" causes. Most of those causes are related to AI and high-tech doomsday prepping, and are intended to benefit humanity in the extremely long term, centuries from now – a philanthropic stance known as longtermism.

Indeed, many EA adherents believe the most effective form of philanthropy shouldn't focus on today's victims of poverty, homelessness and war, but on entrepreneurs who promise to make AI friendly towards humans.

Bankman-Fried served on the board of MacAskill's organisation, the Centre for Effective Altruism, and gave millions of dollars to EA causes. Altman appointed several EA sympathisers to his board, including computer scientist Ilya Sutskever, who has said in a number of places that he believes OpenAI is on the cusp of developing artificial general intelligence, or a human-equivalent mind so powerful that it might constitute an existential risk to humanity (see page 56).

Being affiliated with EA gave the impression that the work the Sams were doing had a higher purpose. They were building a better future, where work and money would be utterly transformed by technology. Plus, they were saving humanity!

But when push came to shove, it appears some of these ideals took a bit of a back seat. Speaking to a journalist during his trial, Bankman-Fried said that his investment in EA was partly "dumb shit" he said to make himself seem ethical. For his part, Altman claimed to care about grave existential risks caused by OpenAI projects. But at the same time, he was deploying and selling an untested technology he himself had called potentially dangerous – a move many effective altruists view as irresponsible. Perhaps the commitment of both men to EA was more about words than deeds.

Silicon Valley truly is a capitalist Thunderdome, where two Sams enter and one Sam leaves. Sadly, the losers are all of us in the crowd, cheering them on. ▮

No planet B

Graham Lawton on climate backpedalling

I WILL remember 2023 as another year of sadness and anger, and not just because of my personal loss. Constant alarming news on the environment coupled to a political class still largely unable or unwilling to heed the warnings from scientists frequently make my job a gloomy place.

This is especially so in the UK, where our shopping trolley of a government has veered alarmingly to the right on a lot of what ex-prime minister David Cameron – recently resurrected as foreign secretary – once called "green crap". Pledges to max out North Sea oil and gas; motorist-friendly policies; row-backs on net zero; crackdowns on environmental protesters. Those in power obviously think these are vote winners, showing a depressing eagerness to seek short-term gains by dismissing or denying long-term problems. One of my big hopes for 2024 is that they are proved wrong at the ballot box.

Fighting back against the green crap is all part of the war on woke, another thing that has made me despair this year. Somehow, attempts to make the world a fairer place for everyone and a greener one for nature have been weaponised by those for whom the status quo is just fine.

I am a white, middle-aged, home-owning, heterosexual, able-bodied male (he/him), so the war on woke rarely touches my life directly. But I'm also a cyclist and a tofu muncher and I live in north London, so anti-woke politicians really wind me up. But that is what they are trying to do, so I will try to be zen about it.

I have learned, though, how casual, careless use of language can offend. I am also a SOBS – a survivor of bereavement by suicide. There is a trigger phrase in that community: "committed suicide". This is a throwback to the time when suicide was a crime. It isn't any more, but the phrase has stubbornly stuck. When I hear people say my wife committed suicide, I have to bite my tongue and then gently point out that many SOBS find it offensive. Completed, please. Or just plain English: she killed herself.

Some people will probably regard this as "wokeness" and yet another example of how "you can't say anything these days". But I hope it demonstrates that being anti-woke can be unnecessarily hurtful. It doesn't cost anything to be sensitive to others' feelings. It is a small thing. But it gives me a taste of what LGBTQ+ people, those with disabilities, ethnic minorities, environmental protesters and other marginalised groups must feel when their hard won gains or lifestyles are smeared as "wokeness".

Don't get me wrong – I'm privileged to do the job I do and I will keep on doing it. And there have been highs among the lows. I travelled a lot this year, though narrowly avoided a few hairy situations. I was in Morocco just before the earthquake, Israel just before the Hamas attack and Iceland just before the volcano. I recently spent a few days in Dorset. My advice: avoid this English county, something bad is going to happen there.

On top of that, I think our rivers campaign helped move the issue up the agenda. Our Rewilding Weekender was great, not least because I got to meet so many of our wonderful readers. Ditto New Scientist Live. And I landed a prestigious journalism award.

I write this as COP28 begins in Dubai. Hopes aren't high, but they spring eternal. There is still time to avert a triple catastrophe of climate change, biodiversity loss and pollution. Just don't get me started on the US presidential election. ▮

Our human story

Michael Marshall hails a rewriting of prehistory

AT THIS point, it is a truism that the story of human evolution is undergoing an overhaul. Discoveries in recent years have forced us to reconsider many crucial points, such as how old our species is (about 300,000 years as opposed to 200,000).

This year was equally dizzying: discoveries continued to come thick and fast. But I do think it is possible to draw out some overall messages from the blizzard of finds. Two things stand out to me. One is the growing evidence that many supposedly advanced behaviours, such as architecture and art, can be traced much further back in time than we thought. And the other is that we have badly misunderstood gender roles in prehistoric societies.

Let's start with architecture. At Kalambo Falls in Zambia, researchers found buried logs that had been shaped with stone tools so they interlocked. They seem to have once been part of a larger structure, perhaps a building. This would be unsurprising if they weren't from 476,000 years ago, almost 200,000 years before *Homo sapiens* evolved.

Art also seems to have been invented by older hominins, and 2023 saw more Neanderthal works found in La Roche-Cotard cave in France. Earlier species like *Homo erectus* may have made art too, by engraving patterns on shells.

By far the most contentious claim in this area is that *Homo naledi* made art. This hominin lived around 250,000 years ago. It had quite a small brain, which is typical of older species – and was therefore believed to be

> **"Many supposedly advanced behaviours can be traced much further back in time than we thought"**

incapable of complex behaviours.

Nevertheless, in the Rising Star cave system in South Africa, where the *H. naledi* remains were found, scientists have discovered what seem to be etchings on the walls. They also claim to have found evidence of *H. naledi* burying its dead in the cave. To say these claims are controversial is to understate the situation. Many researchers say the evidence presented so far is completely inadequate to support them.

In a sense, we shouldn't be surprised that so many of these behaviours seem to have origins in older, extinct hominins. The idea that there was a sudden explosion of creativity at some point in our evolution isn't inherently ridiculous: sometimes a system hits a tipping point and undergoes runaway change. But there was never much evidence that human evolution worked this way. Instead, it seems *H. erectus*, the Neanderthals and many others all walked so we could run.

One way or another, the *H. naledi* story will be an example of letting our preconceptions get in the way of the evidence. The same is true for our ideas about gender in prehistory. Archaeology was invented by societies with sexist ideas, and those notions bled into the research. This year saw some major steps in unpicking this stuff.

Perhaps most dramatic was the demolition of "Man the Hunter". This was the idea that, in most prehistoric societies, men went out to hunt and women stayed home. However, a meta-analysis in June compiled data on several dozen foraging societies and found women hunted in 80 per cent of them. We have also seen growing evidence of women occupying positions of power in ancient societies, such as an Iberian leader from around 4000 years ago who turned out to be female, not male as had been assumed.

I want to end on a hopeful note. The more we learn about past societies, the more our preconceptions about how society "has to be" are upended. Inequality and patriarchy aren't inevitable. They are choices, and prehistory shows we can choose differently. ▮

Field notes from space-time

Chanda Prescod-Weinstein chases the cosmos into 2024

THIS year I made what may have been a mistake: I agreed to write two books. And having written that sentence, I feel compelled to reassure both of my editors (should they see this column) that all is totally fine, I am on top of this and you will get my drafts by the agreed dates.

Both books, in different ways, are about the cosmos and my (maybe strangely) enduring love for the thing. I say strangely because of the year we have had – turmoil on Earth might make the wider universe seem less relevant. But there is a cosmos beyond the bad things humans get up to and there are people getting up to great things too.

I find the pressure of working on my second and third books kind of terrifying having won some awards for my first one, *The Disordered Cosmos: A journey into dark matter, spacetime, & dreams deferred*. But I have found pleasure in one element of preparing for the task: reading what other people have to say in order to deepen my knowledge of the concepts I plan to write about.

The book I need to do the most reading for is an academic one, which is different from what we call a trade book, which is the kind aimed at general audiences. Academic books are typically put out by university publishing houses and academics are generally the main audience, although many of them are written with a crossover to the general market in mind.

My proposal for this book went through peer review, and I had to respond to feedback from anonymous commentators, making the case for how I would address perceived weaknesses. A trade book never has to go through this process and is only vetted by its editor.

I have given myself something of a challenge with this academically oriented project, tentatively titled *The Cosmos Is a Black Aesthetic* and which will be published after the tentatively titled *The Edge of Space-Time*, which is my next book on science for generally curious readers, like those of *New Scientist*.

In the former, I am bringing together ideas from Black studies, feminist thought, history of science, philosophy of science and the theory of aesthetics, which is the corner of philosophy concerned with art. I have no formal training in any of these areas, although I have now been working at them long enough that people in some of these fields see me as something of a peer.

It is possible I don't know what I am doing. But it also means that I have got an excuse to do some reading that stretches my imagination. For example, I'm poring over *The Dialectic Is in the Sea: The Black radical thought of Beatriz Nascimento*, edited and translated by Christen A. Smith, Bethânia N. F. Gomes and Archie Davies. The late Nascimento was a Black Brazilian cultural worker who had some fascinating notions about the metaphysical relationships between Black feminism, space and time.

"The tentatively titled *The Edge of Space-Time* is my next book on science for generally curious readers"

As someone trained in the Anglosphere, I am relishing this opportunity to understand how Black thinkers around the world used the cosmos as a palette for freedom dreaming.

I think after the year we have had, that is exactly the kind of influence I need as I chase quantum fields into 2024. ▮

Tackling common disease burden through clinical trial innovation

Clinical trials are the difference between treating with hope and treating with knowledge.

With an explosion in therapeutic opportunities — personalised cancer vaccines, gene-editing for lifelong cholesterol reduction, annual injections to lower blood pressure and novel therapies to prevent the onset of dementia — clinical trials are essential to establish whether what looks good in the lab is safe and effective in practice.

Overcoming clinical trial challenges

The need for such advances is pressing — the burden of common diseases, health disparities and increasing healthcare costs — while life expectancy for many falls. However, the traditional clinical trial enterprise isn't suited to tackle these big challenges. Many promising treatments never enter late-stage development; many that do are only studied, and therefore only ever used, in niche populations.

COVID-19 showed that when the incentives of the drug development industry, healthcare system, patients and wider society are aligned and when clinical trials are appropriately designed and delivered, we can generate the evidence needed to tackle a major health threat.

Shaping successful clinical trials

The RECOVERY Trial (which I co-led) enrolled over 48,000 patients, producing global practice-changing results in just a few months and saving over a million lives. Initiatives such as NIHR's 'Future of UK Clinical Research Delivery' and the US Advanced Research Projects Agency for Health's (ARPA-H) innovation network offer substantial investment in infrastructure and governance.

However, for real improvement, we need to significantly update the way trials are conducted — with patients as partners. That's why we established Protas. We work across sectors to design trials that provide compelling answers to important questions by making full use of advances in information technology and the availability of real-world health data (with appropriate safeguards).

We work with patient communities and clinicians to increase participation. We work with policymakers to shape regulatory guidelines to embrace innovation and facilitate the generation of reliable results.

We might be coming out of COVID-19, but other 'pandemics' (areas of major disease burden) are hiding in plain sight. By recognising and actively applying clinical trial innovation, in the UK and elsewhere, we can start to drastically transform global health, people's lives and the health systems supporting them.

Professor Sir Martin Landray
Chief Executive Officer, Protas

Ways to strengthen the **clinical research ecosystem** in resource-limited settings

Encouraging clinical research in low-income settings is essential to tap into opportunities that can make a difference in patients' lives.

Creating a sustainable clinical research ecosystem requires open and close collaboration. The pharmaceutical industry is a crucial contributor to this ecosystem in designing, initiating and running global clinical trials according to the highest regulatory and ethical standards. It has been working closely with academics, national regulatory authorities, patient communities and funders to support and strengthen the capacity to conduct clinical research in resource-limited settings.

Key pillars of clinical research

From industry experiences on the ground, and in line with the WHA resolution on Clinical Trials, several key pillars are needed to enable this ecosystem:

- Adhering to international regulatory and ethical standards to ensure the safety and wellbeing of participants and patients' timely access to medicinal products.
- Fostering population diversity and inclusiveness in clinical trials in line with the guiding principles for design and conduct of multi-regional clinical trials and taking into consideration ethnic differences in global clinical trials as described in the international standards ICH E17 and ICH E5 respectively.
- Investing in the necessary infrastructure for site governance of trials through more sustainable infrastructure, upskilling and innovation for the benefit of pandemic preparedness and boosting R&D capacity in resource-limited settings.
- Enhancing clinical research capacity through international public-private partnerships and, more importantly, through local community involvement and ownership for building and retaining a solid local network of experts.

Initiatives enabling clinical trial functions

In Africa, the industry and other partners are collaborating to build clinical trial capacity in ethics and regulatory oversight through initiatives such as the Clinical Trial Community African Network, which collects regulatory and ethics information for African clinical trialists and the WHO African Vaccine Regulatory Forum (AVAREF).

Strategies for clinical research growth

Improving the clinical research environment in resource-limited settings is a multi-stakeholder endeavour. Central to this effort are trust-building, the sharing of best practices and the use of reliance mechanisms for clinical trials. Together, these collaborative strategies pave the way for a more innovative and sustained approach to advancing clinical research in underserved regions.

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Streamlining clinical trials: overcoming the diagnostics challenge

As clinical trials become decentralised/hybrid with people increasingly taking part from home, a major challenge remains collecting samples for diagnostic testing.

Monitoring participants' vital signs via wearable technology is becoming commonplace in clinical trials. Yet, the collection and analysis of diagnostics remains a logistical challenge. On-site tests require participants to visit a trial site — a burdensome request when they're far away.

Consumer-centric technologies

CEO and Co-Founder of Thriva Solutions, Hamish Grierson, points to a wealth of exciting participant-centric technologies that are making trial participation more convenient. "It's why decentralised clinical trials and (DCT) hybrid trials are gathering momentum," he says.

"However, unless diagnostics follow suit, they will remain a real handbrake to innovation. If we cannot collect samples from participants at home, then there's still a need to travel and attend physically."

Self-sampling at home

"Diagnostics are the most cumbersome part of the participant experience," adds Grierson. "We're providing a solution to the challenge of omni-channel diagnostics. We enable multiple test types coordinated through a single, scalable platform," he says.

The platform covers tests such as HbA1c, cancer subtyping and genotyping across core areas of metabolic disorders, genetics, liver disease, cancer and cardiovascular conditions. Self-sampling kits sent directly to participants for blood, urine, saliva and stool samples are returned to a network of carefully selected laboratories by post.

Screening and recruitment

By running their own software across the entire supply chain, samples are linked to kits and individuals to avoid errors or mismatched results, providing end-to-end traceability. It also enhances the pre-recruitment screening process, encouraging a broader dataset from a more diverse population.

"The platform reduces trial costs and participant churn and enables more geographically varied participation," he continues. "Being able to find the right people will only increase the calibre of the screening programme."

Stage 1–4 and real-world evidence

Screening is not the only application for remote diagnostics within the clinical trial lifecycle. There are many other viable uses: pre-chemotherapy tests; post-market surveillance; companion diagnostics; dosage titration, etc.

At-home diagnostics advantages

The benefits of at-home diagnostics are extensive: improved participant experience; cost savings; greater diversity; improved convenience; reduced carbon impact due to reduced travel. Grierson concludes: "We are bringing clinical trials into the 21st century to ensure that pioneering treatments reach those most in need."

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Hamish Grierson
CEO & Co-Founder, Thriva Solutions

WRITTEN BY
Mark Nicholls

Find out more at **thrivasolutions.com**

Breaking down the barriers of **academic multinational trials**

In Europe, almost half of clinical trials are carried out by academics in University Hospitals and other public organisations. While most industry-sponsored trials are multinational, the vast majority of investigator-initiated trials are conducted in a single country.

Jacques Demotes
Director General, ECRIN

Even though some academics develop solutions with novel treatments, diagnostics or vaccines, their work often focuses on comparative effectiveness (comparing authorised treatment strategies); treatment optimisation (improving the current treatment regimen or combining treatments); or drug repurposing (exploring new indications for already approved drugs).

Challenges in multinational trials

When developing a trial, the researcher must ensure its feasibility, including access to enough patients and medical expertise to generate high-quality data and statistically robust results. A great way to overcome these issues is to plan a multinational trial, which can come with many other benefits including access to experienced clinical facilities and investigator networks. This is of particular importance for rare diseases but can also benefit large-scale trials in all disease areas.

Initially, the idea of opening the trial to other countries can seem straightforward, but the rarity of this approach in the academic world is challenging. Many barriers exist that can quickly deter even the most experienced researchers: differing national regulatory and ethical approvals, diversity of languages, availability of cross-border funding, contracting with hospital sites, etc.

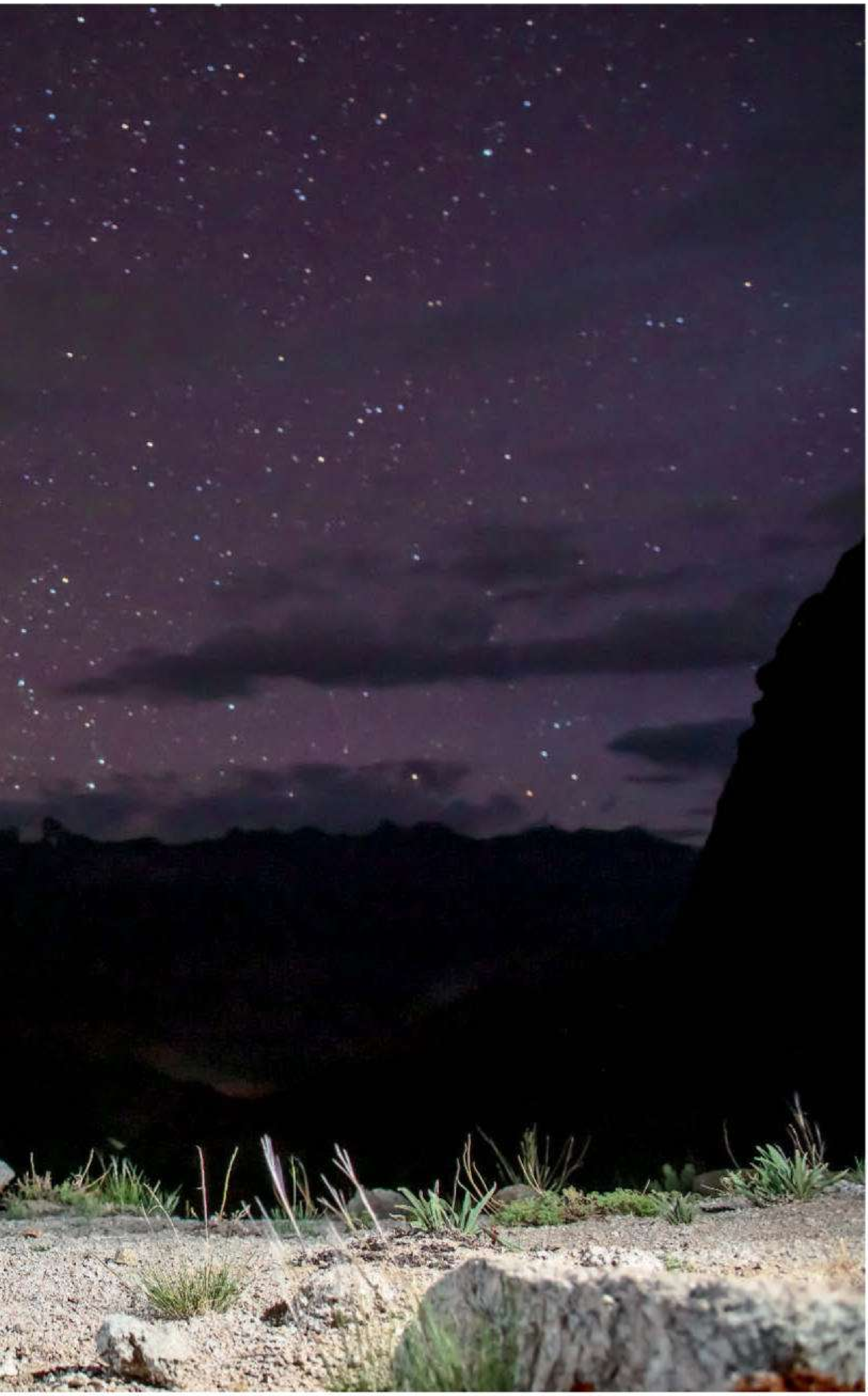
Supporting multinational trials

While European policies and regulations promote enhanced harmonisation and coordination, researchers still need support to bring their ideas to fruition. The European Clinical Research Infrastructure Network (ECRIN) was created to support academic researchers (and small and medium-sized enterprises) planning and conducting multinational trials, in any disease area.

With staff located in all its member countries, it is directly connected to the local clinical trial unit networks and has experience in coordinating these with the entity responsible for the trial.

With expertise in different clinical study modalities, it supports investigators and sponsors in the planning and design phases and then provides coordinated trial management services (at a non-profit rate) during implementation. ECRIN also advocates for the academic clinical research community and develops tools to facilitate working across borders.

Martina Esdaile
Communications Officer, ECRIN



Star of the show

Photographer **Morup Namgail**

IT TAKES a special kind of patience to search for a ghost. It is unlikely you will find one, but doubt means quitting, so you keep looking.

This is the art of tracking snow leopards. Morup Namgail learned it early. He was 5 when he first saw one in his remote home village of Uley in Ladakh, India. The area teems with wildlife – heaven for aspiring photographers like Morup and his brother Stanzin. These large cats, locally referred to as *shan*, were immortalised in the BBC series *Planet Earth II* thanks in large part to their father, Norboo, who tracked them for the crew.

Ladakh was just becoming famous for sightings – then the pandemic shut everything down. That is when the brothers vowed to photograph something no one had before: a snow leopard under a starry night sky. They hoped the image would highlight the beauty of this mountainous region and its apex predator, thereby spurring efforts to protect both. This is a place warming at double the global rate, threatening the landscape and its wildlife. If the outside world could only see what was at stake, the brothers believed it would influence the government to act.

They spent months blanketing the area with cameras. But halfway through the project, Stanzin died of a heart condition. Hard as it was, Morup pressed on alone.

Last August, on a 33°C (91°F) day, he climbed a 4900-metre ridge. “What I found on my camera was my dream came true,” says Morup. It was bittersweet, though. “In Buddhism we believe in reincarnation. I see snow leopards all the time and often think: what if Stanzin reincarnates as a snow leopard? Probably he would pause for a photo or maybe say hello. Maybe he did.”

Adam Popescu

Lottie and the River

A short story for *New Scientist* by astrophysicist turned award-winning science fiction author **Alastair Reynolds**

IT WAS a foggy December, colder than usual.

An old woman waded through the shallows of a concrete-bound river. She wore overalls and a breather mask, a meshwork hopper slung over her back. She leaned hard on two sticks, one with a grabber on the end, the other a net. At intervals, she scooped some grey, slimy clump from the river and deposited it in the hopper.

Dusk was falling as the woman paused for breath. She rested on the sticks and took off her mask. She gazed at the fog-shrouded stratoscrapers rising either side of the river, searching their mirrored facades. Lights were coming on, yellow rectangles against the colourless grid. Occasionally, a human silhouette appeared behind the glass, an anthracite statue looking out. They rarely looked down.

Big yellow taxis sped overhead, shuttling between the upper levels. Drones zigzagged on repeating errands, stitching fading, angular lines into the clouds and fog. Periodically, a larger one descended all the way to the river, collecting a loaded hopper and depositing an empty one in its place.

Lottie had been working the salvage contract for a week. It paid poorly and the conditions were terrible, but she just needed to stick it out a little longer, banking enough credits to reconnect with her daughter.

Just a couple more weeks, then Lottie would be with Amelia again.

It was all going well until the newcomer arrived, climbing down one of the rusting ladders hooked over the raised lip of the flood defence.

Lottie waded over, keen to spike this misunderstanding.

“Hey, friend,” she said, pulling her mask aside. “Welcome to the river. But I think you’ve got the wrong sector.”

The figure entered a boot at a time then turned. Her mask dangled from its straps. She was a much younger woman, shorter and leaner than Lottie. She possessed a sharp, feral face, two close-set eyes like double-tapped bullet holes.

“Say what?”

“I said this isn’t your sector.” Lottie nodded agreeably in either direction. “Just check with Global. Any help needed, come find me.”

The woman tightened her hopper straps, squaring bony shoulders against the coming load. “Think I got the right sector, mama. Sure you haven’t made a mistake yourself?”

“I’m pretty sure they’d have told me if there was a problem.”

“The problem is you weren’t getting through the assignment quick enough.” The young woman – she was 20 at the most – shrugged unconcernedly. “But you’re OK. They’re not taking you off the job just yet.”

Lottie bristled. “Just as long as we keep out of each other’s hair.”

“Where’ve you swept?”

“You saw the direction I was working in. Figure it out for yourself.”

“And a warm welcome to you too.” She made a mocking salute before fixing the mask. “Have a nice life, mama.”

She waded off, making quick progress through the boot-sucking shallows. She sang something, some refrain filtering through the mask, some words about Christmas and cutting down trees.

#

They avoided each other for a couple of days. The river swung a kink through the canyon of stratoscrapers, the other woman usually out of sight.

Lottie was just starting to think that she could deal with this arrangement when the newcomer came wading purposefully in her direction.

Lottie leaned in on her sticks, lifting her chin pugnaciously.

The woman removed her breather when they were close enough to speak. She held up her grabber.

“You know how to fix one of these?”

Lottie glanced at it with cursory interest. “What’s your problem?”

“It’s jammed.”

“Call in for a new one.”

“That’ll mean time when I’m not earning creds. I thought maybe…”

Lottie grunted. She made a terse, bad-tempered gesture. “Bring it over.”

The woman waded nearer. She looked tired, shrunken-in on herself, as if the river had taken its toll in just these few short days.

“I just thought maybe…”

“Old mama could fix it.” Lottie took the jammed grabber. She took off a glove, instructed the woman to hold it while she used her nails to pop open a seam.

EOIN RYAN

“Like this,” she said, exposing the innards. “Watch carefully because I’m not showing you twice.”

She freed up the mechanism, worked the grabber a few times, fixed the cover back into place.

The woman took the grabber, passing Lottie her glove. “Thanks… I guess.”

“It’s nothing.”

They stood there in silence for a few moments. Yellow machines zipped overhead. The buildings stood severely truncated by the fog, only their elephantine foot-slopes rising from empty plazas.

“Blue,” the woman said.

“Blue what?”

“It’s my name. Blue.”

Lottie nodded slowly, some part of her certain that the best thing was to say nothing, to turn away

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Biography

Alastair Reynolds

After working as a scientist with the European Space Agency, Alastair Reynolds turned full-time writer in 2004. His science fiction novels include *Eversion* and the forthcoming *Machine Vendetta* (2024), both published by Orion.

and carry on with her work.

"Lottie."

"I didn't mean to tread on your turf."

"So long as you keep a few markers up or downstream, you won't be."

After another silence, Blue said: "Won't be here too long, anyway. I just need a few more creds for the Up And Out." She nodded into the clouds.

Lottie made no effort to mask her scorn. "You think it'll be any different up there?"

"It'll be something." Blue's dark, close-set eyes examined her searchingly. "I just need a change. What about you?"

"Me? I'm here because I love wading through sick rivers in winter, collecting junk."

"Guess we should be grateful."

Lottie blinked. "Grateful?"

"That we still have a use. What I hear, this is about the last thing robots can't do for themselves."

Lottie had heard the same thing. Robots could sort the junk, clean and grade it, recycle it back into more robots, more drones, more telepresence proxies, but the one thing they were bad at was getting the junk out of the river in the first place. They got stuck, becoming more junk in the process.

So for the moment – until the cost/benefit equation tipped minutely in the other direction – it was cheaper and easier to employ humans.

"You noticed many drones falling into the river lately?" Lottie asked.

Blue gave her a blank look. "I'm supposed to?"

"They're getting more reliable. Things don't drop out of the sky very often. What they're paying us to fish out – it's a non-renewable resource, the way coal and oil used to be. Once we're done with this sweep, there won't be much more work down here."

"They'll find something else. My friend used to say, there's no bottom to the food chain." Blue gave an easy shrug. "Anyway, I'll be elsewhere."

"Well, good luck with that."

Annoyance pinched Blue's colourless features. "You're so wise, how come you're stuck down here doing the same job as me?" She planted her hands on her hips. "You've got a plan, right? Some point to those creds?"

"I've got a plan," Lottie said.

#

Of course it had been a mistake, exchanging names. Now Blue seemed to feel the need to shoot the breeze at least once a day. Lottie went along, guardedly. They fell into an unspoken arrangement, climbing out of the water when their hoppers were ready for collection, sitting on the bank not too far apart, legs over the edge, boots dripping back into the water, waiting for the drones to swoop in.

"How was your haul?" Blue asked.

"Fine." Lottie brooded for a few seconds. "And yours?"

Blue rubbed a hand under her nose. "Had better. Hard to pick out the good stuff, sometimes. If I throw back the low-grade waste, I'll just end up scooping it up again."

"You can't really win, you know that? The best you can hope for is not to get screwed too hard, too quickly."

"I'm all right. Another 800, then I'm out of here. One-way ticket on the slev to Quito, maybe enough left over for some of those neural mods." She showed Lottie her credit card, the tally glowing in snowy digits.

"You might make that in a week, maybe two, nothing goes wrong."

"What I'm counting on." Blue hummed to herself, rubbing absently at raw-rimmed eyes.

"What's that thing you keep singing to yourself?"

"You really want to know?"

"I'm the one has to listen to it."

"Some music my mother used to play me. Some song about Christmas coming on and cutting down trees." She hummed a little more. "Something about river, and skating away. Or wanting to." She dipped her face, some shadow of sadness passing across it. "It's nothing. Stupid song, anyway. It's cold here, but it'll never get cold enough for the river to freeze."

Lottie reflected quietly before answering. The light was sullen, advertising banners pushing through jackdaw clouds, scribbles and flickers of nervous yellow.

"Your mother's up there? Is that why you want to take the Up And Out?"

Blue sniffed again. "No, she's long gone." She jammed defiance into her voice. "But I remember her. I always will, and that stupid damned song."

Lottie dug into one of her waterproof pockets and came out with a little squeeze-tube. "The river's getting to your sinuses. Smear this around your nostrils. Make sure that breather's fitting properly, too."

Blue accepted the tube. She squeezed a small dab of the grey gel onto her fingertips. "Thank you."

"Don't want you getting sick on me. They might send someone worse."

#

Despite herself, Lottie came to appreciate these minor interludes of human contact. It was an unsettling epiphany, as if she had become a traitor to the cooler part of herself.

"I hope you make those creds," she said, a couple of days on. "Whatever you do, though, promise you won't blow a single › one of them on neural mods."

"That you speaking from experience?"

"I had retinal degeneration. A congenital condition. Back when I had money, I stumped for Chromeguard implants. Full vision restoration."

Blue looked at her curiously. "There's a downside?"

"Chromeguard were bought out. The new firm had a different subscription model. I couldn't make the regular payments." She paused, shuffling on the bank as the concrete chilled her bones. "I mean, I could, but only at the expense of something else." She mulled the yellow-flecked fog. "What happens is that they turn off the receptors one by one, taking away your colour perception."

A frown notched Blue's brow. "So the world is… what?"

"Mostly monochrome," Lottie said. "Mostly shades of grey."

#

They worked to their different rhythms, Lottie slow and discriminating, Blue quicker but not so careful, but the two of them always finding time to sit and talk while the drones came in.

"What was your mother doing listening to music from a hundred years ago?"

"She was weird. She didn't really belong in this century."

Lottie chuckled quietly. "I'm not sure any of us do."

"She was cool, though. She wanted more for me than this. More than just being at the bottom of the heap. I'll turn things around, though." Blue raised her eyes to the sky again. "There's a life for me out there. It might not be perfect, but it'll be closer to the one she had in mind."

"I hope you make it. Be sure to send me a postcard."

"A what?"

"Just send me a message, tell me how you're doing." Lottie sat silently for a few long moments. She felt on the brink of something dizzying, as if the drop to the water had become a thousand vertical metres. "I had a daughter once. Her name was Amelia. She's lost to me now."

Blue took her time answering. "You don't talk?"

"She's dead. One of those mid-century 'demics they probably taught you about in school. When I say lost, I mean I can't reach my memories of her."

"What happened to them?"

"They're paywalled."

"I don't understand."

"The company was called Mnemonic Gate. Neuroprosthetic memory storage and retrieval services. They put something in you, deep in the hippocampus."

"There was something wrong with you, like the eye thing?"

"No. They put it in me because my employer insisted on it, a condition of work. That wasn't uncommon. Mnemonic Gate was an offshoot of Cloud9, and Cloud9 was part of Omniserve, and Omniserve was basically running the world. They said jump, you said how high."

"All right. Pretty sucky. I guess you had Omniserve, we have DEUS and Gladius Biomech and Global Workspace. What went wrong?"

"Another case of buy-outs and mergers and changing terms. Suddenly I ended up having to pay to maintain Mnemonic Gate 'legacy services'." Lottie gave a morbid little laugh. "If I didn't cough up, my own memories stayed locked away. Including the entire part of my life with Amelia."

Blue sat still. A slow rage formed on her face. "That's not right."

"It isn't, but what could I do? For a while, I managed the payments, managed to hold onto Amelia. But I was running just to stand still. I couldn't meet the rising fees, so I lost her again. A second death, but worse than the first because this time it was my failing, not the fault of some damned virus."

"It wasn't your failing!" Blue said fiercely.

"That's what I tell myself, but it doesn't always work. Especially around this time of year. She liked Christmas. It gets raw. Same thing happens each time: I make one last bid to raise enough to buy back my memories, take on whatever work I can find."

Blue nodded forlornly. "That's what it's about for you, then. Trying to earn enough creds to own the thing that already belongs to you." She snarled. "Screw them! Screw DEUS, screw Global Workspace, screw Omniserve!"

Lottie smiled. "I got angry too. It fades, eventually. There's no point being angry. You can't stay like that all the time."

"You have to earn those creds," Blue said with sudden conviction. "How short are you?" She made a motion toward her own card.

"No," Lottie said firmly. "We're not doing that. Besides, I'm way off. And even if I was close, I'd still have to make a choice. My world isn't totally monochrome. I kept up the payments on yellow."

"Yellow?"

"It was Amelia's favourite colour. Yellow Christmas lights, her yellow bicycle, yellow crayons, her first dress. These things I remember. The colour, her favourite ice cream, the sound of her shoes on the hall, the smell of her. It's secondary, though – a whole suite of peripheral feelings, with the centre gone. Like a galaxy of yellow stars with a vast black hole at the middle."

"I'm sorry," Blue said quietly. "You'll get her back one day, won't you? You'll find a way to make those payments?"

"That's the plan," Lottie said flatly. "Got to have a plan, right?"

#

It all became clear in retrospect, hours after the bad thing itself.

Blue stopped work suddenly and came wading over to Lottie, ghost-faced and shivering.

“What?” Lottie asked concernedly.

“They…” But Blue could hardly form the words. Lottie took hold of her, squeezing her tight, both up to their hips in filthy water.

“Tell me.”

“They’ve deducted 600 credits.”

“There has to be a mistake.” Lottie snapped her fingers. “Show me the card.”

Blue did. There had been no error.

“They told me,” Blue said, still shivering in her embrace. “It was something I dug up out of the muck. Some kind of damaged power-pack or maybe a bomb someone left in the river. The drone collected it. It went all the way back to the grading facility, then it blew up.”

Lottie shuddered. Down in the fine print, they were responsible for any damage to upstream assets, anything or anyone higher in the food chain, robot, AI, human.

“Was anyone hurt?”

“No,” Blue sniffed. “I think it was just machines. But it’s still cost them.”

“You mean it’s cost you.” Lottie steeled herself. “You need those creds, girl. We’ll say there was a mix-up, that the bad thing was in my hopper.”

“We try that, they’d just punish both of us.”

“They would.” Lottie felt something shift within herself, some piece of her soul moving silently and irrevocably into a new configuration. “And even if you stayed here for another month, who’s to say it wouldn’t happen again?” She paused. “Show me your card.”

Some glimmering of understanding reached Blue. “No. This is my mistake; I’ll own it.”

“It’ll be my choice.”

“I don’t want it. You need what you’ve earned, for Amelia.”

“Amelia’s gone,” Lottie said, suddenly dry-mouthed. “I’ve known that a long time; I just wasn’t able to face the truth.”

“She’s still there, behind the paywall.”

“Something’s still there. Maybe my memories, maybe not. Would I even know, at this point?” Lottie shook her head, furious in her defiance. “No. What mattered about her, I’ve still got. Those traces of her I clung onto. Those yellow things. The feelings that surround the void. It’s enough.”

“You’re only saying that because you want to help me.”

“I’ve been thinking about what it would mean to pay for those memories. I’d be surrendering, giving in to them.”

“Why would helping me be any different?”

“Because it’s a human deed they don’t get to monetise. Because right now, you need this more than I need Amelia.” She swallowed. “Because it would please me to do one good thing for a friend. Because… hell, it’s Christmas.”

“If I take this offer… promise me you’ll be all right?”

“I’ll be fine. Like you said, there’s never a bottom to the food chain.”

“I hope you’ll take care of yourself.”

> **“She’d found regular work, some rare niche that still needed a particular quirk of human talents”**

“I will. And you’ll send me that postcard. Tell me about the Up And Out.”

Blue extracted her card. Lottie offered hers to it and authorised the credit transfer. The digits on her card tumbled down, while those on Blue’s incremented.

“Thank you,” Blue breathed.

“That’ll get you to Quito?”

“And more. I promise I won’t use any of it on those mods.”

“Good girl. I mean, at some point you’ll probably have to, but at least you’re going in with your eyes open.”

“I am.”

“Don’t let them take anything more from you than they need to, Blue. And keep singing that song. It’s not stupid wanting to skate away, even if the river never freezes. It’s beautiful.”

“I promise.”

Blue left. She had no reason to finish her shift, and what remained in her hopper she invited Lottie to tip out and load into her own, one small recompense.

Lottie watched her walk away from the bank, diminishing to a tiny spectre against the rising flanks of the buildings. Fog curdled low, forming a platinum screen. Blue waved a hand, turned around and stepped into the mist. Lottie never saw her again.

#

She did hear from Blue, though. After about three months, she sent a message to say that she was finding her way in the Up And Out, that it was tough, but she was adapting. Three months after that, another message. She was doing better now. She’d found some regular work, some rare niche that still needed a particular quirk of human talents. It might not last, but she was keeping her options open.

It was nearly six months before the next message, and that meant it was nearly a year since they had worked the river together. Lottie was somewhere else by then, no longer scraping muck and mud for recyclables. It wasn’t better work, exactly, but it was a change. Something different.

Blue was doing well now. She had gone further out. She was starting to find that her skills were valuable, to the right people. She was making better money. It was expensive, out there, but she had begun to save more than she was spending. And she wanted to send a little bit of those funds back to Lottie.

“I know it’s not as much as you gave me,” Blue said, older and wiser in just the 12 months she had been away. “And no kindness of mine can equal the thing you did for me, back when I needed it. I still want you to have this, all the same. Maybe it helps you get a bit closer to Amelia, if that’s what you still want. Just don’t think of it as surrendering, however you make use of it. You’re better than that, and you’re better than them. I’ll always be grateful that we worked that stinky old river together.”

Lottie did the decent thing, which was to accept the gift. When the transaction had completed, she closed her hand around the card, treasuring the memory of her sharp-faced friend from the river, hoping that things kept on working out for Blue. Then she went and wandered the grey world until, with an equal measure of pain and joy, something yellow stabbed her right through to the core.

Editor's pick

Climate notes from a very small island

9 December, p 8

From Phyl Rendell,
Bleaker Island, Falkland Islands

We are deeply concerned about climate change and the need to do our bit here in the Falkland Islands. We live on a small island and produce our own power from solar and wind, store water and deal with our waste and rubbish ourselves. We have been planting native tussac grass into eroded ground over the past 20 years to sequester carbon. It creates extra habitat for wildlife too.

Climate change has caused dryness, lack of grass growth and ponds drying out. We are now reducing our sheep and cattle numbers as farming is becoming unsustainable and we must put the health of the island first.

I visited Europe this year and there seems to be no obvious sign of people trying to reduce their carbon footprint or their contribution to profligate waste. In fact, the opposite is evident. The lack of cheap and efficient public transport in the UK, for example, resulting in so many vehicles on the roads (electric or not) gives the impression that no one cares. People in high-income countries must start living with less if there is to be a future.

Human innovation gives me cause for optimism

Letters, 25 November

From Chris Uruski,
Featherston, New Zealand

Reader Ian Elliott pessimistically suggests naming the first age of the Anthropocene Epoch "The End". Whatever happens to our species, the planet will still be here. It has been through worse climate fluctuations in the past.

In any event, human minds are generating ideas to ameliorate climate change if given a chance. Neocrete, with volcanic ash replacing at least part of the cement used for concrete, has the potential to cut emissions by 2 per cent if adopted worldwide. We read in the same issue (p 19) of electrocaloric cooling twice as efficient as standard air conditioners. We also learn (18 November, p 22) that mining spoil can yield elements and minerals for advanced machines.

All hail the shift to a transparent market

2 December, p 40

From Martin Sigrist,
Newbury, Berkshire, UK

I welcome Graham Lawton's look at true cost accounting, the idea that goods factor in the environmental and social damage they cause. It is a step towards a true free market where consumers can exercise real choice. I would encourage a look at other ideas. For example, B-Corp certification could be a de facto standard for differentiating good from bad business. And the Better Business Act is a proposed change to UK law that would make firms align interests with those of the environment and wider society.

AI predictions are more like fantasies

2 December, p 8

From John Reynolds,
Canonbie, Dumfriesshire, UK

The article about AI and the crystalline structures it can "predict" is responsibly tempered with information about the accuracy of the results and concerns about the practicality and stability of these materials.

This raises a question of language: at what point do we anthropomorphise AI? When do we say, "the crystals that AI can *imagine*", as a way of acknowledging that, whether from humans or AIs, exciting ideas are ten-a-penny?

Our brains really aren't quite that superlative

Letters, 14 October

From Tom Reimchen, Victoria,
British Columbia, Canada

As a long-time subscriber and reader, I continue to disagree with the cliche that the human brain is "the most complicated structure in the known universe". What actually is the evidence for this?

Some 50,000 years ago, when early modern humans were cowering in caves with the same essential anatomical brain and genome we have at present, no alien visiting Earth would have recognised any great potential of this biped relative to Neanderthals or any other primate, or to the many large-brained cetaceans. To claim that the brain of those early cave-dwelling humans was the most complicated structure in the universe is yet another instance of human-centric thinking.

Hope of finding treatment for Huntington's disease

25 November, p 10

From Carlos Estevez Fraga,
Huntington's Disease Centre, UK

In a recent article on Huntington's disease, expectations for a successful disease-modifying therapy were set low. However, the presence of mutated huntingtin protein is clearly associated with the development of symptoms. It is therefore reasonable to think that lowering huntingtin can change the disease course.

Three unsuccessful huntingtin-lowering trials were mentioned. However, a post-hoc analysis of one has revealed possible benefits for younger people with a low disease burden, leading to ongoing testing. Additionally, the company responsible for the two remaining failed trials has introduced an improved version of its drug, currently undergoing human testing. Finally, two more trials are exploring huntingtin-lowering strategies. Both have had promising preliminary results.

Setbacks are common and frequent in science. However, when the cause of a condition is known and there are methods to target it, it is only a matter of time until successful treatments are developed. There is hope for those with Huntington's disease.

Why not try this way of finding alien life?

25 November, p 40

From Fred Richardson, Alice Springs,
Northern Territory, Australia

When it comes to how to detect signs of life on other worlds, I think the assembly theory idea from Lee Cronin and Sara Walker needs expanding on. It relies, currently, on readings from mass spectroscopy, MRI and infrared interrogation of molecules to derive a complexity scale. In this system, molecules that score below 15 could have been formed in the random happenstance of cosmic chemistry, while those above 15 have been shaped by evolution and/or technology. With a bit of luck, Cronin and Walker might get working access to NASA's Dragonfly mission to Titan, which will carry a mass spectrometer.

There could be downsides to fattening up when old

2 December, p 12

From Barbara Wyvill,
Kettlestone, Norfolk, UK

The idea that older people should be encouraged to fatten up a little is a pernicious one. Extra weight means extra effort in moving around and may discourage exercise; in addition, a poor diet is unhealthy in many ways, not just because it may cause weight gain. ▮

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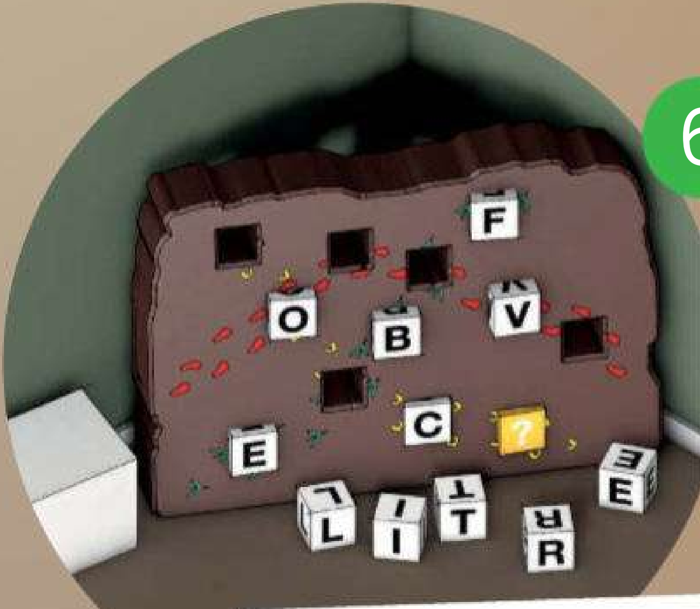
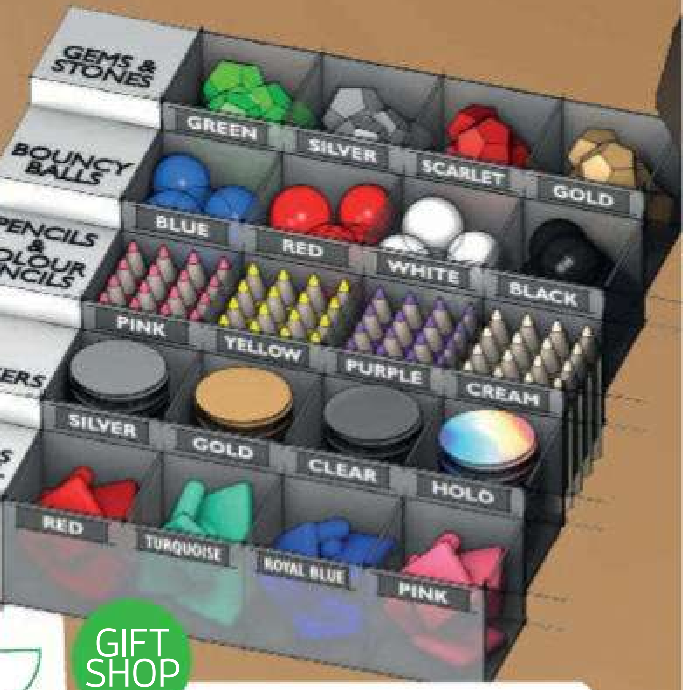
MYSTERIES OF THE MUSEUM

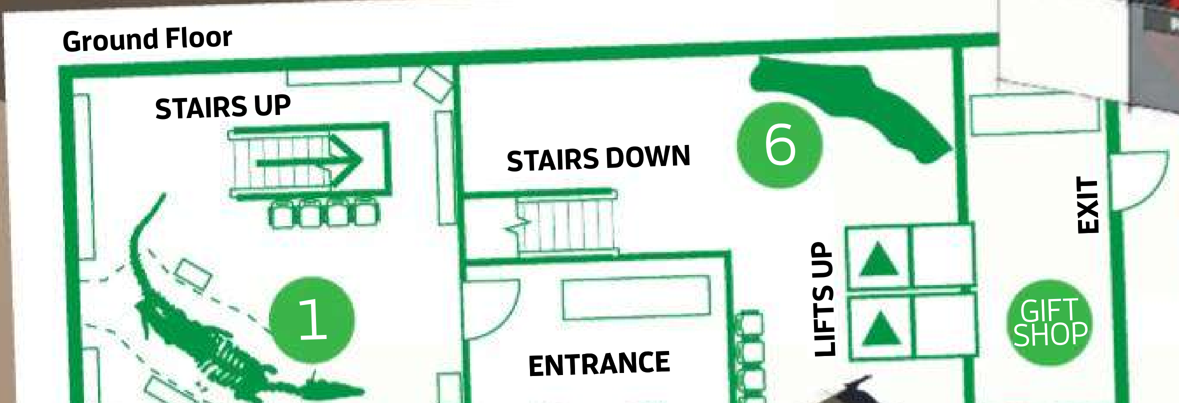
Welcome to *New Scientist*'s fiendishly difficult holiday puzzle! This year, the action takes place at the museum on Viewpoint Road – and the challenge is to figure out the street number of the building. Start by visiting the exhibits and the gift shop, each of which contains a puzzle that, when solved, gives you a letter. Put them all together for a steer on how to navigate the museum and figure out the number. If you get stuck, there is a hint at the bottom of page 41. For the final answer, visit **newscientist.com/museumpuzzle**



6

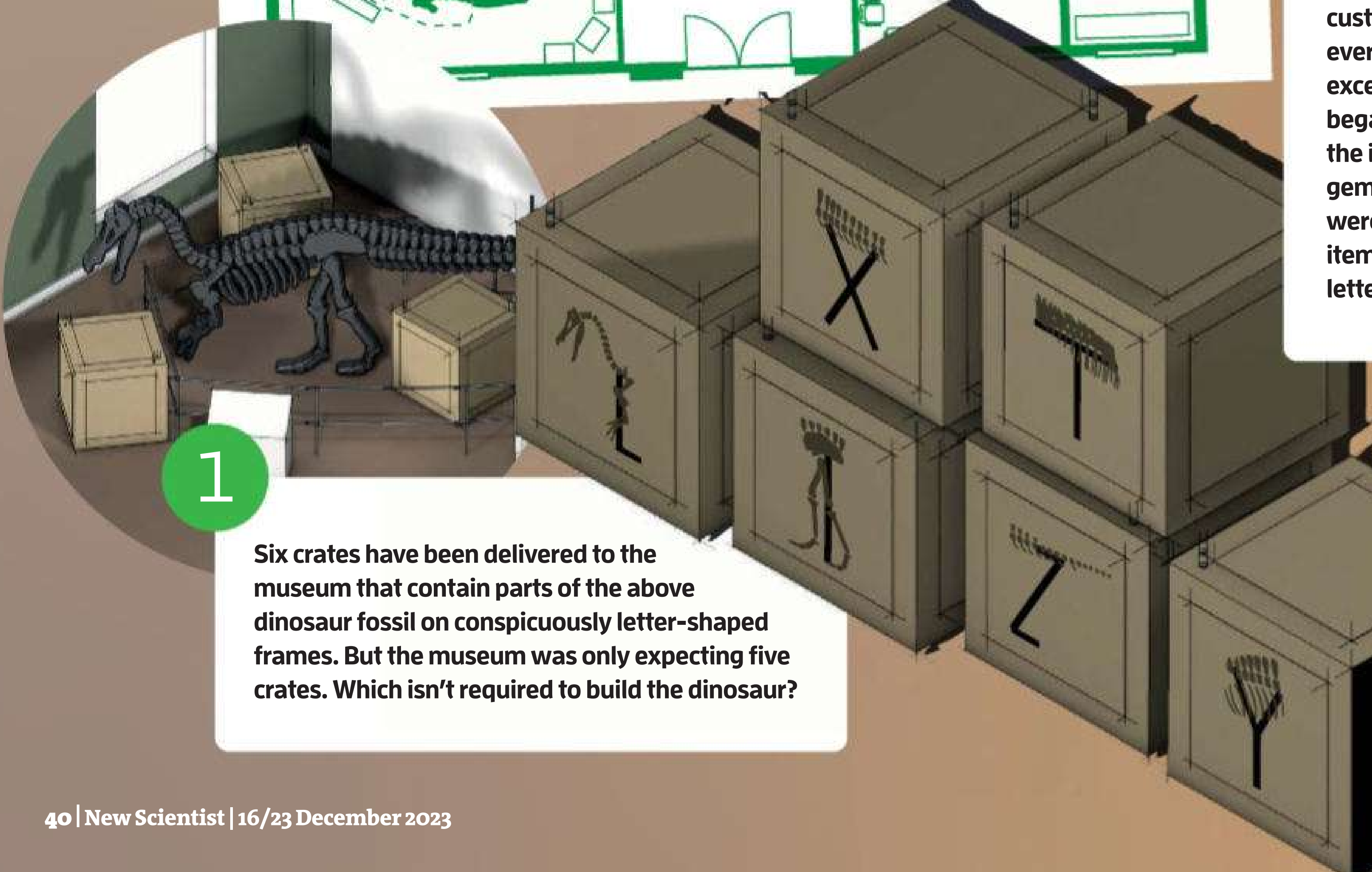
This exhibit follows three ancient trails left by a person, a bird and a horse. Along each trail are letters that make a five-letter word when completed. But some of them have fallen out. Can you fix the exhibit and work out which letter you would need to replace the yellow brick?





GIFT SHOP

Before you leave, pay a visit to the gift shop! The image above shows the counter fully stocked, but a rather peculiar customer has just bought every item from the display except the ones whose colour began with the same letter as the item (for example, no gold gems or turquoise toppers were bought). The remaining items should now resemble a letter – which?



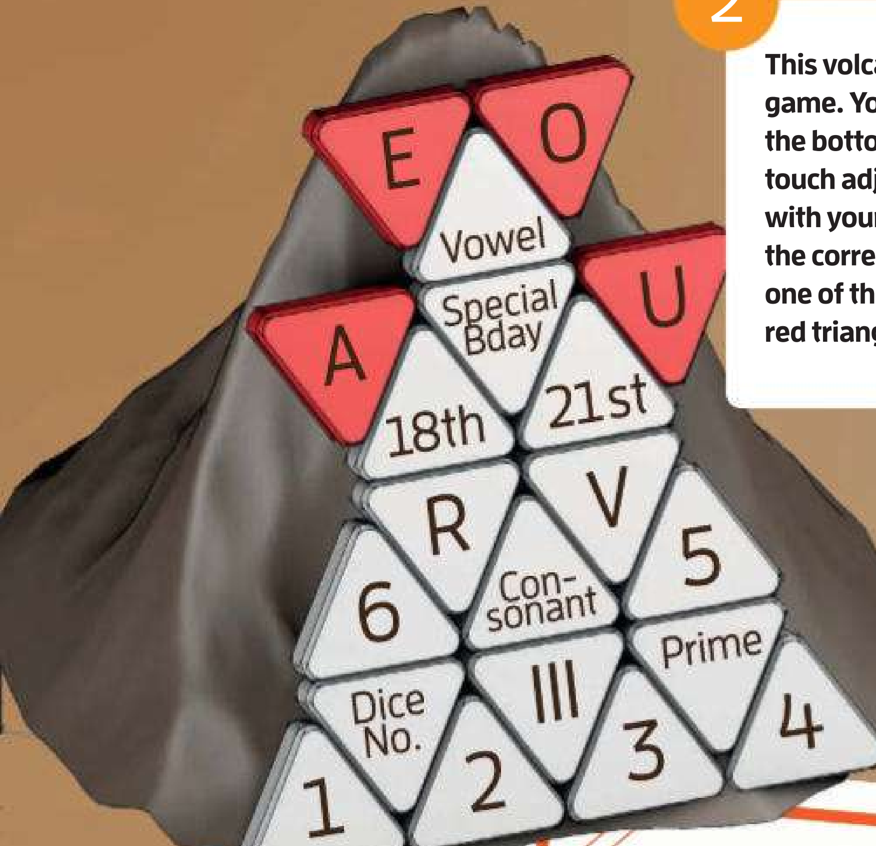
1

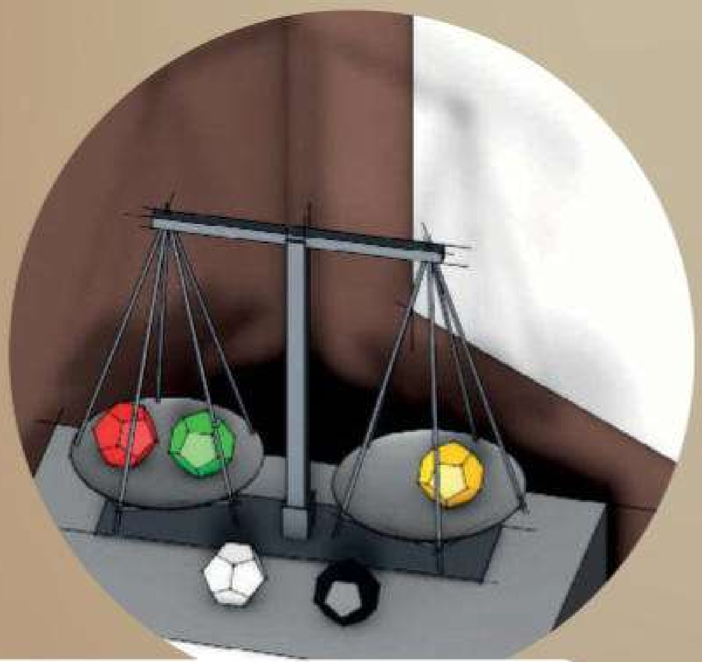
Six crates have been delivered to the museum that contain parts of the above dinosaur fossil on conspicuously letter-shaped frames. But the museum was only expecting five crates. Which isn't required to build the dinosaur?

PUZZLE DESIGNED BY CHARLIE WHEELER AT ULTIMATE QUEST

2

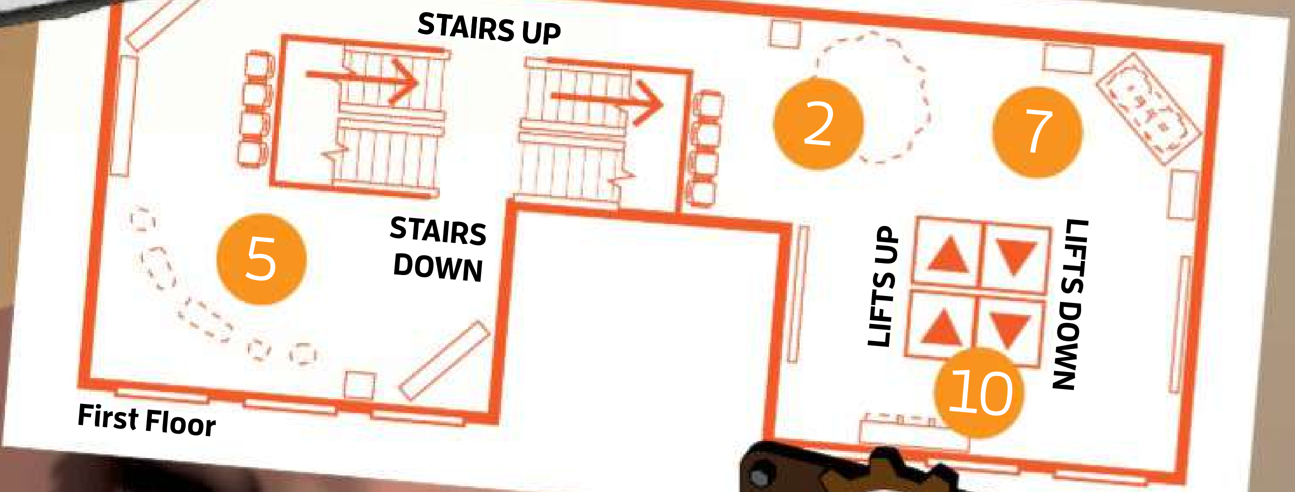
This volcano exhibit is an interactive game. You start by touching one of the bottom row of triangles, then touch adjacent triangles that match with your previous one. Can you find the correct route from the bottom to one of the four red triangles? Which red triangle is last in the chain?

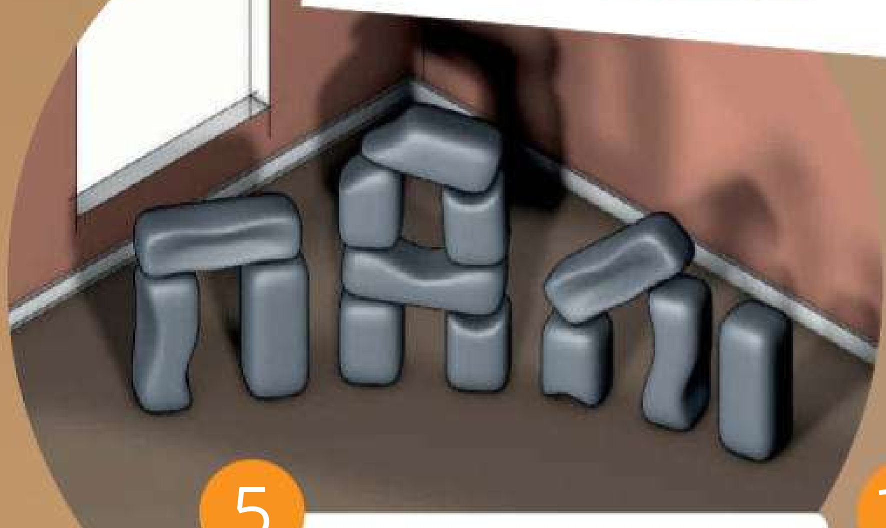


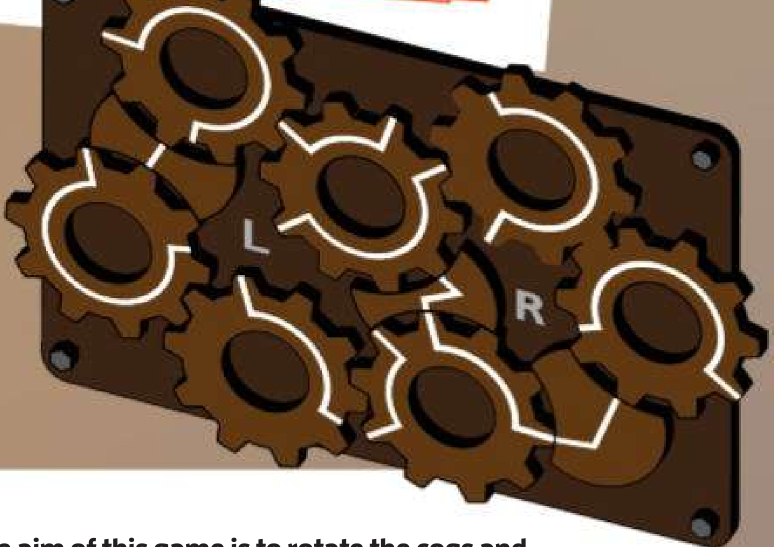


7

According to the posters next to this set of scales: a red ball weighs twice as much as a green one; a green ball weighs twice as much as a white one; a black ball weighs the same as a green one and a white one. Without moving the yellow ball, can you make the scales balance with all five balls on them? If so, which side of the scale has the most balls on it, left (L) or right (R)?







5

This stone circle exhibit consists of a collection of foam stones. There are eight unique designs of these stones. If you were to ignore all duplicate shapes, what letter would be remaining?

10

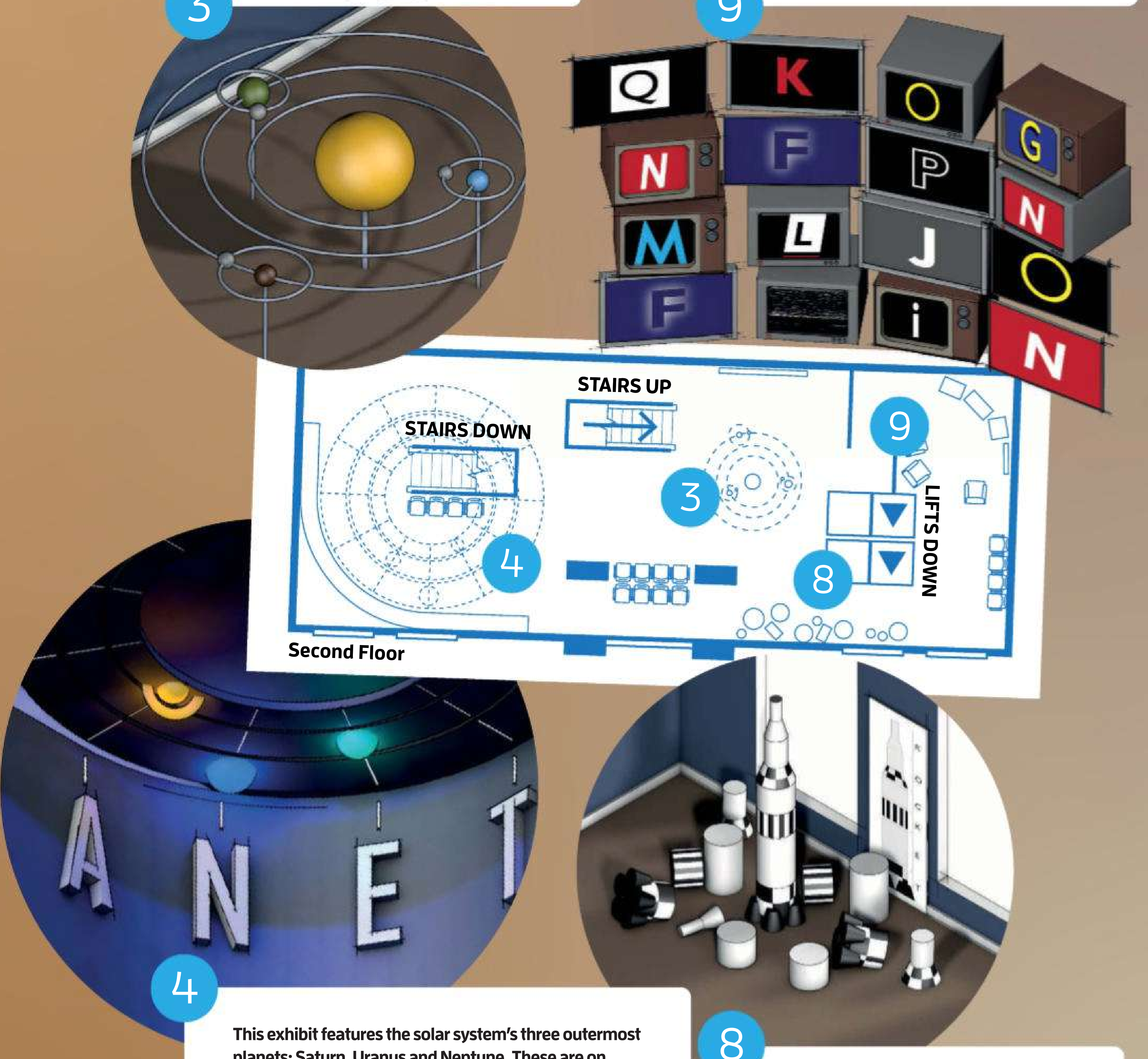
The aim of this game is to rotate the cogs and create a complete circuit along the silver lines. However, only one circuit can actually be made. Which of the two letters on the back plate can be surrounded by a complete circuit?

FINAL PUZZLE HINT: Once you have solved all 11 puzzles, try tracing your path through the museum, considering the building from all angles. ANSWERS: [1] The unnecessary crate is T. [6] The yellow block should be an H. [GIFT SHOP] The unemptied boxes form a lower case 'e'; [2] The correct route is 3, Prime, 5, V, Consonant, R, 18th, Special Bday, 21st, ending with the answer U. [5] Ignoring all the duplicates would leave you with an F. [7] The correct answer is L (left). It would have three balls on it, red, white and black. [10] The solution is L. R can't be made.

Once an hour, this exhibit's sun lights up to demonstrate the different phases of the moon. If you were to look towards the sun from the innermost of the three planets, what would you see (C, O or D)?

◐ ◉ ◑

In this grid of screens, channel 1 broadcasts an image of a letter A, channel 2 a B and so on. In each row and column of the grid, the channel numbers add up to the same total value. Which letter should be broadcast on the blank TV in the bottom row?



This exhibit features the solar system's three outermost planets: Saturn, Uranus and Neptune. These are on ceiling-mounted rings, which have 12 spokes and rotate clockwise at speeds that reflect the differences between the planets' orbits. Uranus takes three times as long to complete an orbit as Saturn, and Neptune takes twice as long as Uranus. If you waited for Saturn to do a full orbit, which letter would Neptune be over?

At this exhibit, museum visitors can build their own rockets using these pieces and the guide on the wall. Originally, there were enough pieces to make multiple complete rockets with none left over, but one piece is now missing – which?

ANSWERS: [3] The innermost planet would see an eclipse, an O. [4] Neptune would be above the T. [8] There are three of everything except for the top cone, R. [9] Each row totals 50, therefore the missing TV is 21, or U.

Rock-a-bye spider
Inside the strange dream worlds of animals p44

Mystery of the quantum lentils
Are the legumes talking in secret? p47

Iceberg cowboys
Why explorers are lassoing frozen fresh water p54

Mappa mundi
The medieval map that kick-started cartography p66

The strangest Christmas dinner
Testing a new theory of flavour p70

PEXELS/VLADISLAV MURASHKO

Yuletide yarns

Welcome to *New Scientist*'s festive features, a package always guaranteed to surprise and delight. This year, among other things, we ask why nature never invented flightless bats (page 50), hunt down the extreme life forms living in your kitchen (page 64) and raise a glass to celebrate the physics of cocktails (page 62). Happy holidays!

In their dreams

Do other animals dream? And if so, what do their unconscious minds conjure while they're sleeping, asks **Michael Marshall**

ONE autumn day in 2020, Daniela Rößler drove home with a car full of jumping spiders. Her lab was closed due to covid-19 regulations, so, after a day in a dry field spent corralling her specimens, Rößler had no option other than to bring them back to her house. When, by chance, she checked on them that night, the spiders were dangling motionless by threads of silk. "I had never seen this before," says Rößler, a behavioural ecologist at the University of Konstanz in Germany, who soon went back to the field with her colleagues. "We started filming them, just out of curiosity," she says.

They observed the same behaviour, but only at night. Stranger still, some months later, close monitoring in the lab using a night vision camera revealed not only that the spiders were twitching slightly but also that their eyes were moving. That is similar to what happens when humans dream, which raises the irresistible prospect that spiders could be dreaming too.

Jumping spiders aren't the only non-human animal in which we have recently found evidence of dream states. We are seeing hints of dreaming, and even nightmares, in species throughout the animal kingdom – from pigeons to octopuses. "If we appreciate the functions that could be connected with dreaming, it totally makes sense for animals to dream," says Rößler. And yet the question remains: do other animals dream like we do and, if so, what they are dreaming about? Figuring this out isn't easy but it is worth doing, not least because it might even help us to fathom the purpose of human dreams.

To dream, first you have to sleep, and there is no known animal that doesn't slumber, says Rößler. Recent studies show that sleep is essential for even the simplest organisms to reset their minds and bodies. Even some jellyfish, which have a distributed net of neurons rather than a true brain, behave as though they are tired when kept awake at night by pulses of water sent into their tanks. "Maybe sleep evolved before brains evolved, as a very fundamental thing that is required on a cellular level," says Rößler. It may enable animals to get rid of waste products and toxins that build up when they are active, she adds.

When humans sleep, we do so in two ways that alternate throughout the night. The first is rapid eye movement (REM) or active sleep. During this stage, our eyes move, even though our eyelids are closed. Our muscles also twitch slightly, though they are largely paralysed so we don't hurt ourselves. In contrast, we also engage in non-REM or quiescent sleep, during which we barely move at all. Most dream states, and certainly those with the most vivid dreams, happen during REM sleep.

Ancient dreamers

There is plenty of evidence that other mammals have similar sleep patterns to humans. In 2022, for example, researchers observed the brains of sleeping mice and found increased activity in neurons that respond to the direction the animal is facing. That suggests the animals were looking around, as humans do in REM sleep.

Finding evidence of dreaming itself in non-mammals has proven more difficult. Non-mammals' brains are very different to those of humans, and it can often be difficult to image them while they are sleeping. In June 2023, however, Gianina Ungurean at the Max Planck Institute for Biological Intelligence in Seewiesen, Germany, and her colleagues succeeded in recording brain activity in awake and sleeping pigeons. They first habituated the birds inside a fake functional magnetic resonance imaging (fMRI) scanner before swapping it out for a real one to obtain the first brain scans of sleeping birds. As in mammals, the recordings revealed bouts of REM and non-REM sleep.

Intriguingly, REM sleep activity was high in brain regions involved in processing visual

JASON FORD

information, especially images that slide across your field of view when you are in motion – a phenomenon called optic flow. "These activities, put together, are indicative of birds flying," says Ungurean, who tentatively suggests this is what the pigeons were dreaming about.

Ungurean also found that during non-REM sleep in pigeons, cerebrospinal fluid flushes through the brain, washing out toxins – but this happened much less in REM sleep. The implication, she says, is that REM sleep has an essential function too. "We need this REM state," she says, otherwise we wouldn't have traded cleansing, non-REM sleep for it.

That said, dreaming and REM sleep probably aren't universal in the animal kingdom, says Paul Manger at the University of the Witwatersrand in South Africa. For example, sponges don't have brains, or even neurons, so they lack the machinery for dreaming.

There are also some animals with unusual sleep patterns. These include whales and dolphins, which sleep with half of their brains awake and show no sign of REM sleep. One interpretation is that they only experience less vivid non-REM dreams. This feels counter-intuitive, says Manger, because we tend to think of whales and dolphins as having complex inner lives. He reasons that during REM sleep, the body's thermoregulation system is impaired, leaving animals more vulnerable to extremes of temperature. This could be dangerous for marine mammals sleeping in cold water. "To me, it looks like it's an adaptive thing to prevent hypothermia," he says.

Nevertheless, in many cases REM sleep does seem to have benefits. Growing evidence from birds and mammals suggests that REM sleep and dreaming are important for forming memories and learning. "Events are replayed during sleep," says Ungurean, which helps to integrate memories into longer-term storage. As soon as animals evolved moderately complex lifestyles, they would have needed to dream in order › to "learn and contextualise", says David Scheel at Alaska Pacific University in Anchorage. This happens by rerunning variations on experiences.

Pigeons, though, are much more closely related to humans than spiders are. Our last common ancestor with arthropods and other invertebrates lived over 500 million years ago. Sleep and dreams in invertebrates have been almost ignored, says Rößler. That is partly due to prejudices about invertebrates – that they are primitive and lack complex inner lives – and partly due to the practical challenges of studying them. But in recent years, the field has begun "slowly, finally, cracking open", she says.

Unable to keep spiders still inside a brain scanner, Rößler had to find new methods for measuring sleep activity. Jumping spiders have retinal tubes inside their eyes that they can angle to shift their field of vision. Using tracking software that precisely measured how these tubes moved, she observed behaviour akin to REM sleep.

Rößler is careful to specify what her findings show. "We haven't properly demonstrated that they're even asleep," she says, as sleep is conventionally defined by the behaviour of mammals. Still, Rößler points out that when the spiders' eyes were moving, their legs were curled inwards – a behaviour only otherwise seen in dead spiders, due to a loss of internal pressure. "We feel like this is a very similar thing to the muscle atonia and paralysis that we see in sleeping mammals and birds," she says. Rößler is now studying sleep in 20 different spider species and so far has found "the exact same patterns" in every single one.

Patterns like these are suggestive, but we still don't understand how this outward behaviour relates to internal experience. It seems impossible to know what it is like to be a spider or a pigeon, let alone imagine their dreamscapes. We are quick to interpret the twitching limbs and muted barks of sleeping dogs, but the truth is that we don't know if there is an internal experience of chasing rabbits that comes along with that.

Another invertebrate dreamer offers insight here. Cephalopods, such as octopuses and cuttlefish, were observed to have REM and non-REM sleep states over a decade ago by inferring from changes in colouration and arm twitching while the animals slept. But in the past few years, close observation of cephalopod behaviour, alongside brain imaging studies, hint at an even richer inner world.

In 2019, while making a documentary, Scheel housed an octopus named Heidi in a tank in his living room. At one point, in the middle of the night, Heidi seemed to dream: her limbs and head moved, and her skin rapidly changed colour, as though she was pursuing a crab.

QUINTON SMITH/BBC/PASSION PLANET

QUINTON SMITH/BBC/PASSION PLANET

Octopuses and spiders show behaviours that resemble human dream states

Similarly, in May 2023, a report emerged of a sleeping octopus apparently having a nightmare. Costello, as the octopus was called, thrashed around, extended his mantle as if trying to make himself look bigger, and squirted ink as though he were being attacked by a predator. The nightmare study is intriguing, says Scheel, but is only based on one animal. He argues that as well as outward behaviour, brain imaging is needed to show that the octopuses are replaying sequences of activities from their waking lives in dreams.

"Jumping spiders' inner worlds may be composed of thuds and shakes"

This kind of parallel brain activity has already been observed for octopuses hiding from danger. In June 2023, Leenoy Meshulam at the University of Washington in Seattle and her colleagues reported implanting electrodes in nine octopuses to observe their brains while awake and asleep. Daytime patterns of activity associated with octopuses camouflaging themselves were also replicated during sleep.

For Scheel, the evidence is at least consistent with the idea of octopuses having a nightmare while they sleep. If humans dream in order to process emotionally intense experiences, then perhaps octopuses do too. An octopus that shows evidence of experiencing fear in a dream is likely to be dreaming of a familiar predator, says Scheel. But in the case of Costello's apparent nightmare, he says we don't have enough data on "how octopuses respond in the moment to traumas" to prove it.

The trouble is, says Scheel, that we will never be able to experience any animal's dreams other than our own. That goes for other humans' dreams too. But we can try to imagine what these dreamscapes are like by meeting animals on their own terms, says Rößler. For example, vision is the dominant sense for many humans, and so our dreams are heavily visual too. Dogs primarily navigate the world using smell, and bats echolocate. Spiders, meanwhile, rely much more on vibrations. So, if jumping spiders do dream of helpless insects, their inner world is likely to be composed of thuds and shakes.

These experiences emerged hand in hand with the environments animals have evolved in. Given these vast possibilities, it is likely that dreaming has served multiple purposes since the first complex animals evolved, says Scheel. And this is how animal dreams might shed light on the true purpose of our own.

If we take a more systematic approach, sampling across the animal family tree to discover which groups dream, and how the events of their lives affect their dreams, we could figure out whether dreaming evolved just once, in the earliest animals, or multiple times independently. That, in turn, could offer fresh insights into the evolutionary pressures that cause species to evolve the capacity – and thus shed light on why animals, and humans, unconsciously conjure life-like experiences. ▮

Michael Marshall is dreaming of a white crustacean being devoured by an octopus

The mystery of the quantum lentils

Are these humdrum pulses secretly communicating with quantum signals? **Thomas Lewton** listens in

IN THE foothills to the south of Rome sits Italy's premier nuclear physics lab, the National Laboratory of Frascati. It has all the equipment you would expect at a cutting-edge science facility, with huge magnets, powerful particle accelerators and exposed electric cables spilling out everywhere. Many of the researchers here are trying to unpick the secrets of the standard model, our best theory of how reality works at its most fundamental level. And then there is the room where Cătălina Curceanu is monitoring a small box of lentils.

Granted, it isn't exactly normal behaviour for a physicist, but Curceanu hopes the apparatus and methods of nuclear physics can solve the century-old mystery of why lentils – and other organisms too – constantly emit an extremely weak dribble of photons, or particles of light. Some reckon these "biophotons" are of no consequence. Others insist they are a subtle form of lentil communication. Curceanu leans towards the latter camp – and she has a hunch that the pulses between the pulses might even contain secret quantum signals. "These are only the first steps, but it looks extremely interesting," she says.

There are already hints that living things make use of quantum phenomena, with inconclusive evidence that they feature in photosynthesis and the way birds navigate, among other things. But lentils, not known for their complex behaviour, would be the most startling example yet of quantum biology, says Michal Cifra at the Czech Academy of Sciences in Prague. "It would be amazing," says Cifra. "If it's true." Since so many organisms emit biophotons, such a discovery might indicate that quantum effects are ubiquitous in nature.

Biophotons have had scientists stumped for precisely a century. In 1923, biologist Alexander Gurwitsch was studying how plant cells divide by placing onion roots near each other. The closer the roots were, the more cell division occurred, suggesting there was some signal alerting the roots to their neighbour's presence. It would be useful for plant roots to signal in this way, says Cifra, because it would tell them if other plants were germinating nearby, suggesting a fertile growing space.

To tease out how the onion roots were signalling, Gurwitsch repeated the experiment with all manner of physical barriers between the roots. Wood, metal, glass and even gelatine dampened cell division to the same level seen in single onion roots. But, to Gurwitsch's surprise, a quartz divider had no effect. Compared to glass, quartz allows far more ultraviolet rays to pass through. Some kind of weak emission of UV radiation, he concluded, must be responsible.

Invisible light

Living organisms have long been known to communicate using light. Jellyfish, mushrooms and fireflies, to name just a few, glow or emit bright flashes to ward off enemies or attract a mate. But these obvious signals, known as bioluminescence, are different to the effect Gurwitsch had unearthed. Biophotons are "a very low-intensity light, not visible to the naked eye", says Curceanu's collaborator Maurizio Benfatto. In fact, biophotons were so weak that it took until 1954 to develop equipment sensitive enough to decisively confirm Gurwitsch's idea.

SPOOKY POOKA

Since then, dozens of research groups have reported cases of biophoton emission having a useful function in plants and even animals. Like onion roots, yeast cells are known to influence the growth rate of their neighbours. And in 2022, Zsolt Pónya and Katalin Somfalvi-Tóth at the University of Kaposvár in Hungary observed biophotons being emitted by sunflowers when they were put under stress, which the researchers hoped to use to precisely monitor these crops. Elsewhere, a review carried out by Roeland Van Wijk and Eduard Van Wijk, now at the research company MELUNA in the Netherlands, suggested that biophotons may play a role in various human health conditions, from ageing to acne.

There is a simple explanation for how biophotons are created, too. During normal metabolism, chemical reactions in cells end up converting biomolecules to what researchers called an excited state, where electrons are elevated to higher energy levels. Those electrons then naturally drop to their ground state and emit a photon in the process. Because germinating seeds, like lentils, burn energy quickly to grow, they emit more biophotons.

Today, no one doubts that biophotons exist. Rather, the dispute is over whether lentils and other organisms have harnessed biophotons in a useful way. "It's intriguing," says Greg Scholes at Princeton University. "Could that emission be used as a signal?"

The idea is unproven, to be clear, but it isn't as far-fetched as you might think. We know that plants communicate using chemicals and sometimes even emit ultrasonic squeaks when stressed. This allows them to control their growth, warn each other about invading insects and attract pollinators. We also know › they have ways of detecting and responding to photons in the form of regular sunlight. "Biological systems can detect photons and have feedback loops based on that," says Scholes. He adds that it isn't unreasonable to think that, if they have systems to detect photons of light, they could have ways of detecting weaker biophotons too. One idea is that this signal could tell cells to somehow metabolically reset en masse, says Scholes. "We don't really know how it works."

Cifra was once an advocate of biophoton signalling, but his enthusiasm waned in recent years when he uncovered more mundane explanations for many of the reports. Last year, for instance, he noticed that one claim of how biophotons affect cell death was actually explained by chemical signalling that hadn't been adequately blocked out. In another recent study, he found only a small difference between the pattern of biophotons being emitted by mung beans and that of a random signal generated by a computer. "I'm not sure that's enough to make it useful for communication," he says, though he acknowledges the emission is so weak that it is hard to be sure.

But Curceanu and Benfatto are hoping that the application of serious physics equipment to this problem could finally let us eavesdrop on the legume's secrets. They typically use supersensitive detectors to probe the foundations of reality. Now, they are applying these to a box of 75 lentil seeds – they need that many because if they used any fewer, the biophoton signals would be too weak.

Quantum characteristics

The pair also knew that there was a possibility of the signals having some quantum characteristics. Quantum particles, which include photons, behave according to the rules of quantum theory, which describes the often counterintuitive behaviour of atoms and subatomic particles. For example, photons can exist in a nebulous cloud of many possible states called a quantum superposition. In this case, the photons are said to exhibit quantum coherence.

Years ago, Benfatto came across a paper on biophotons and noticed there appeared to be patterns in the way they were produced. The intensity would swell, then fall away, almost like music. This gave him the idea of applying a method from physics called diffusion entropy analysis to investigate these patterns. The method provides a means of characterising the mathematical structures that underlie

"Physics could finally give us a way to eavesdrop on the legumes' secrets"

SPOOKY POOKA

complex patterns. Imagine comparing a simple drumbeat with the melody of a pop song, for example – the method Benfatto wanted to apply could quantify the complexity embodied in each.

To apply this to the lentils, Benfatto, Curceanu and their colleagues put their seeds in a black box that shielded them from interference. Outside the box, they mounted an instrument capable of detecting single biophotons. They also had rotating filters that allowed them to detect photons with different wavelengths. All that remained was to set the lentils growing. “We add water and then we wait,” says Benfatto.

In 2021, they unveiled their initial findings. It turned out that the biophotons’ signals changed significantly during the lentils’ germination. During the first phase, the photons were emitted in a pattern that repeatedly reset, like a piece of music changing tempo. Then, during the second phase, the emissions took the form of another kind of complex pattern called fractional Brownian motion.

Suspicious signals

The fact that the lentils’ biophoton emissions aren’t random is an indication that they could be communicating, says Benfatto. And that’s not all. Tantalisingly, the complexity in the second phase of the emissions is mathematically related to the equations of quantum mechanics. For this reason, Benfatto says his team’s work hints that signals displaying quantum coherence could have a role in directing lentil germination.

Cifra warns that claims about the nature of these signals shouldn’t be made based merely on mathematical similarities. Just because something can be described by quantum-style maths, that doesn’t in itself prove the thing is quantum by nature. Curceanu recognises that any sign of quantum effects is still tentative. “There’s something going on there, but we can’t claim to know what,” she says.

Cifra reckons that quantum mechanics is likely to play an important role in biology – for example, in bird navigation – just not through biophotons. The quantum interpretation of the lentils research is “a stretch”, he says. “It can easily be explained by classical effects. I give preference to the simpler explanation.”

Part of the problem with designing experiments like these is that we don’t really know what quantum mechanical effects in living organisms look like. Any quantum effects discovered in lentils and other organisms would be “very different to textbook quantum mechanics”, says Scholes.

CATALINA CURCEANU

Are these germinating lentils communicating in quantum code?

Then there is the question of why quantum mechanics would be useful to lentils at all. Finding quantum effects in biophotons would be a “big deal”, says Scholes, “but it’s an open question about what would the function be”. What evolutionary advantage, in other words, would using quantum signals confer on a lentil? One way to think about this might be with reference to the difference between the workings of a classical computer, which uses bits, and a quantum computer, which uses quantum bits. The two systems work in different ways that mean they are suited to solving different kinds of problems. Perhaps, similarly, any quantum signals passing between the pulses would give them a unique way of sending information – for a purpose we haven’t yet fully discerned.

Another possibility is that quantum communication enables lentils to get messages through without these getting lost in transmission. Since biophotons are emitted by all living things, the lentils’ signals could be swamped by emissions from surrounding organic matter, says Cifra. It is possible, says Scholes, that quantum coherence could enable the signals to pass through, despite this background noise.

Benfatto admits that, so far, the evidence for quantum lentils is sketchy. Still, he is pushing ahead with a new experimental design that makes the signal-to-noise ratio 100 times better. If you want to earwig on the clandestine whispers of these seeds, it might just help to get rid of their noisy neighbours, which is why he will study one germinating lentil at a time. ▮

Thomas Lewton has a feeling his nut roast is trying to tell him something

Walking with bats

Our world is dotted with flightless birds, but there has never been a flightless bat. Why is it so hard for these winged mammals to quit the skies, asks **Graham Lawton**

IN THE undergrowth of a New Zealand forest, something stirs. A small, fuzzy animal is scurrying over tree roots and through leaf litter, foraging for insects and fruit. It scuttles with an odd gait, as if on stilts. Is it a mouse? A bird? No, it's a bat. The New Zealand lesser short-tailed bat, or pekapeka-tou-poto, to be precise.

Bats first took to the skies about 52 million years ago, and they have stayed there ever since. Among the world's 1300 or so species, not one of them is flightless. Most can't even walk very well, which is why many of us would be surprised by the behaviour of the pekapeka-tou-poto, a bat as comfortable on the ground as it is in the air.

But exactly why there are no flightless bats is an evolutionary mystery. The other great group of flying vertebrates, birds, have evolved to be flightless multiple times globally. They often do so on remote islands, such as those of New Zealand, where there is little danger from ground-based predation (at least until humans come along – roast dodo anyone?). In these circumstances, flightlessness is a good adaptation because flying is energetically costly.

As the world's most terrestrial bat, the pekapeka-tou-poto has long seemed key to explaining the curious absence of flightless bats. But research over the past 20 years has revealed a surprise: many other species of bat can also walk. Some can even run. So, what are they doing on terra firma, and can studying them help us work out why evolution has failed to produce a bat that can't fly?

Bats are exquisitely adapted for flight, as is clear to anyone who has marvelled at their aerial acrobatics. Take them out of the skies, however, and it is a different story. Most bats are very bad at crawling. Leaf-nosed bats, ghost-faced bats, horseshoe bats and others are completely hapless on the ground.

Some 50 years ago, bat biologist Terry Vaughan suggested a reason. He argued that features of the bat skeleton may explain why many of them walk so poorly. He realised that the rare confident walkers – which include the pekapeka-tou-poto (*Mystacina tuberculata*) as well as the common vampire bat (*Desmodus rotundus*) – have strong hip bones and legs that look a little like ours, in that they have three fully developed long bones: the femur in the upper leg and the fibula and tibia below. In all other bats, the fibula is a tiny stump that is attached only to the ankle, which presumably leaves these bats weak at the knees.

It is clear today just how well the pekapeka-tou-poto and the vampire bat can walk on their sturdy legs. Back in 2006, Daniel Riskin, then at Cornell University in New York, and his colleagues put the two species through their paces on a specially designed bat treadmill. Their study confirmed that both species have a curious but effective walking style, tucking their wings in and moseying along on their backwards-facing hind limbs and leathery wrists – an arrangement that gives their appendages a stilt-like appearance.

The study also revealed that the vampire bats have a secret skill: they can run. When the treadmill speed reached roughly 0.6 metres per second, the bats broke into a gait that the researchers described as "bounding", leaping from all four limbs at the same time (also called pronking). Imagine having a vampire bat bounding towards you, like a bat out of hell. It was thought at the time that vampires and pekapeka-tou-potos were the only two species of bat to be adept walkers. But we have learned more recently that a number of other species, including some with weaker hips

The vampire bat isn't just an expert flyer – it is also an adept walker

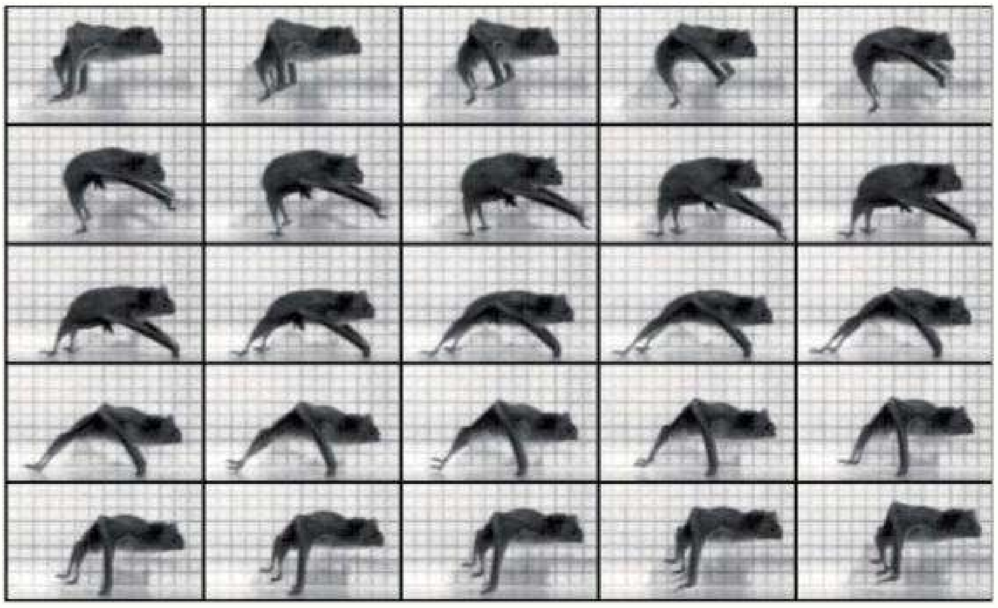
JOEL SARTORE/PHOTO ARK/NATUREPL.COM

and legs, are also powerful, if ungainly, walkers.

Matt Jones at Arizona State University has led some of this research into the walking bats. A few years ago, he had a pest problem at work. He tried using ground-mounted sticky traps to catch the pests – and frequently caught big brown bats (*Eptesicus fuscus*), one of the most common bat species in the Americas. “They were on the ground for some reason or another,” he recalls.

Earlier this year, Jones and his colleague Stephen Hasiotis at the University of Kansas explored further. They stuck some big brown bats in a sandbox with a clear plastic covering and found to their surprise that the bats were ambling around happily and not even attempting to fly.

“They did really well on the ground,” says Jones. The study suggested that weak legs might not be the obstacle to walking that we had assumed them to be – an idea that fits with additional evidence. In 2019, for instance, researchers at Moscow State University and the Severtsov Institute of Ecology and Evolution, also in Moscow, tested five species of weak-legged bat – the common noctule (*Nyctalus noctula*), the parti-coloured bat (*Vespertilio murinus*), the pond bat (*Myotis dasycneme*), Daubenton’s bat (*Myotis daubentonii*) and Nathusius’s pipistrelle (*Pipistrellus nathusii*) – and found they were all pretty adept on their pins.


RISKIN, HERMANSON

MENDESBIO/SHUTTERSTOCK

Although a vampire bat’s legs are short (below, left), it can run at 0.6 metres per second

> **“Imagine a vampire bat bounding towards you, like a bat out of hell”**

But why would these expert flyers lower themselves to our level? As with flightless birds, bats that can walk probably gained the ability because it carries advantages for them. Common vampire bats, for instance, sneak up on prey on the ground and may guzzle so much blood that they are too heavy to fly. The pekapeka-tou-poto’s ancestors, meanwhile, clearly found they could make a good living scurrying around foraging for pollen, fruit, nectar and invertebrates (especially flightless crickets called wetas that are endemic to New Zealand). Today, pekapeka-tou-potos spend about 40 per cent of their foraging time on or under the ground.

Do the locomotion

Whether walking carries benefits beyond feeding or lower energy costs isn’t yet clear, largely because biologists haven’t spent much time studying walking bats. “There’s so little work on the terrestrial locomotion of bats. There’s probably a lot more going on than has previously been suggested,” says Jones.

What little we do know indicates that bats and birds may evolve to spend more time on the ground for different reasons. For birds, it is sometimes an absence of ground-based competitors that seems to encourage the evolution of flightlessness. But Suzanne Hand at the University of New South Wales in Sydney is unconvinced that this model also applies to bats. In 2009, she and her colleagues described a 26-million-year-old fossilised creature discovered in South Australia that is clearly a burrowing bat and also has leg anatomy suited for walking. Australia had no shortage of ground-based mammals 26 million years ago, so this adaptation to also travelling on foot can’t have been driven by lack of competition and predation. Exactly what pushed the ancient bat to begin walking is still unclear.

The differences between birds and bats might also help explain why we have yet to find evidence that any bat, past or present, ever evolved to be flightless. Jones points out that bat anatomy is very different from that of birds. “Their whole body, essentially, from their head down is built to be a flying apparatus. Their wings are comprised not only of their forelimbs, but also of their hindlimbs.” This means it is probably more challenging to remodel a bat body into a fully flightless form.

What’s more, with the way humans have changed the world in recent centuries, the prospects of a flightless bat evolving in the future seem pretty remote. For instance, the rats and cats introduced to New Zealand by humans regularly prey on the pekapeka-tou-poto. Not only does this help explain why the species is now listed as vulnerable by the International Union for Conservation of Nature, it has also upped the selection pressure on the bats to stay airborne, where they hunt successfully for winged insects.

But never say never to the idea of truly flightless bats. “I don’t think it’s impossible,” says Jones. “If somebody came out with a fossil from an island of a bat that lost flight, I wouldn’t be, you know, completely shocked.”

No bats were hurt in the making of this story, though some got very tired running on a treadmill. ▮

Graham Lawton always prefers to walk

Cracking riddles

Stretch your mental muscle by tackling **Leonie Mercedes**'s festive scientific stumpers

1. The most common form of aluminium ore, a wild goat, a rectangular array of numbers and radiation with a wavelength of between 0.01 and 10 nanometres. What do each of these have in common, and why was it in the news this year?

2. Four guests are seated for Christmas dinner. One arrived from a German valley, one is good with tools, one is said to be wise and the other has asked for a chair with a sturdy back. One by one, three of them will leave the table. Which will be the last one seated?

3. In 2028, a crystallographer will join an abolitionist and a fire god. Where are they?

4. Time to gather round the table and do some bonding. Initially, what can be forged from these intriguing combinations of foods?

SWEET NOUGAT + CHESTNUT UDON
CHIPOLATAS + FLAMING EGGNOG
CHOCOLATE UNICORNS + ZESTY NACHOS
ANGEL GINGERBREAD + ASIAN UME

5. How about a brisk walk to work off your Christmas meal? On your journey, you see a large dog, but not on a lead, a big bear, but not in a cave, and a bull, but not in a ring. Where are you looking?

6. Hark! A rapid equalisation of pressure between a vessel and its surroundings has just occurred, creating a fabulously festive oscillation. What just happened?

7. After receiving a clutch of *Turdus merula*, a trio of *Gallus gallus domesticus* and a couple of *Streptopelia turtur*, where might you expect to find a *Perdix perdix*?

8. China's giant Sky Eye has just one, laboratories tend to have a few and Christmas dinner has many. What is it?

9. Three friends decide to play a game of animal, vegetable, mineral. In a bid to stump each other, player A has chosen the source of the world's most widely used antibiotic, player B has chosen the raising agent in bread and player C has chosen the subterranean quarry of a porcine hunter. Why is this game a non-starter?

10. What alcoholic beverage comes next in this list: a government agency responsible for the development of memory foam, an intergovernmental organisation comprising 22 member states dedicated to the exploration of space and a planned experiment designed to detect gravitational waves?

11. The following items have all been left in a specific location: golf balls, a hammer and feather, six US flags and 96 bags of human waste. What vehicles would you need in order to retrieve them?

12. The answer to this one is more basic than you might think, so you should be able to put your finger on it. Assuming they could, why is it that a reindeer might count the 14 days of Christmas, a sloth the 20 days and horses the 1100 days, while dogs and cats would join us in the 12 days of Christmas? (And why would a snake be completely flummoxed?)

13. This boy, who is thought to have been born in December centuries ago, brings warmth to the Pacific but can make winters colder on UK shores. Who is he?

14. In this place, which often comes in pairs, you will find a foot support, a tool for metalworkers, a percussive instrument and something to beat it with. Where is the place, and which of the objects is the odd one out?

15. On the morning of 25 December 1968, after a long journey, people anxiously waited for confirmation of what we had all longed to hear. Eventually, the message came: "Roger, please be informed there is a Santa Claus." What was the profession of the person who sent the message? ▮

Leonie Mercedes is looking forward to hearing many rapid equalisations of pressure this holiday period

TOM GAULD

Answers

1. The clues describe bauxite, an ibex, a matrix and X-rays. Each of these contains an "x", which was in the news in July when Elon Musk rebranded Twitter as X.

2. The guests are each representatives of the genus *Homo*, which, in order, are: *Homo neanderthalensis* (the Latin translation of which is "man from the Neander valley"), *Homo habilis* (meaning "handy man"), *Homo sapiens* (meaning "wise man") and *Homo erectus* (meaning "upright man"). *H. neanderthalensis*, *H. habilis* and *H. erectus* are now extinct – or have left the table in this analogy – so only *H. sapiens* remains.

3. Mars. These titles describe people or deities after whom Mars rovers are named. The crystallographer is Rosalind Franklin, who lends her name to the European Space Agency's ExoMars rover, which is due to touch down on the Red Planet in 2028. She will join two seasoned Mars rovers: NASA's Sojourner, which is named after the abolitionist Sojourner Truth and landed on Mars in 1997, and the China National Space Administration's Zhurong, which touched down on Mars in 2021 and is named after a Chinese fire god.

4. The food combinations describe common alloys, with their initials representing atomic symbols. So, for example, combine Sweet nougat (Sn, or tin) with Chestnut udon (Cu, or copper) and you get bronze. C (carbon) + Fe (iron) = steel, Cu (copper) + Zn (zinc) = brass and Ag (silver) + Au (gold) = electrum.

5. Up. These are all constellations – Canis Major (the great dog), Ursa Major (the great bear) and Taurus (the bull) – that can be seen in much of the northern hemisphere on Christmas day this year, weather permitting. UK stargazers will also be treated to a sight of Jupiter on 25 December.

6. Sounds like someone just opened another bottle of champagne, that festive oscillation being the characteristic pop! That pop, at 600 hertz, is the result of gas rapidly and repeatedly going in and out of the bottle of bubbly right after the cork is released, until the pressure both inside and out is equal. Cheers!

7. The species listed are calling birds (known today as the common blackbird), hens, European turtle doves and the grey partridge, which, as the lyrics of *The Twelve Days of Christmas* suggest, would be found in a pear tree (*Pyrus communis*).

8. A dish. China's Five-hundred-meter Aperture Spherical radio Telescope (FAST), known as Sky Eye, is the world's largest single-dish radio telescope, Petri dishes are often found in labs for growing cultures and dishes of food are likely to be extremely plentiful at Christmas dinner.

9. Every player has chosen a type of fungus: respectively, *Penicillium* (a genus of fungus), baker's yeast and truffles. Fungi aren't animal, vegetable nor mineral. Looks like it is going to be a long night.

10. A mimosa. The answers to the clues are NASA, which in 1966 developed memory foam (then known as temper foam), ESA and LISA. Each of these ends with a vowel followed by -sa, with the vowel sequence in alphabetical order: a, e, i... o.

11. A rocket and a moon buggy. These items were all left on the surface of the moon during the six successful Apollo missions. Why did the astronauts leave all of this stuff behind? To lighten the load before launch and to make room for more moon rocks.

12. This is a question about counting systems. If we work from the assumption that humans' base 10 system originates from our having 10 fingers, we could suggest that animals with eight digits on their two front limbs, such as reindeer, would count in base 8, three-toed sloths would count in base 6 and horses, which have just one toe on each foot, would count in base 2, or binary. The number 12 is 14 in base 8, 20 in base 6 and 1100 in base 2. (Snakes, of course, have no digits at all.)

13. The boy, both figuratively and literally, is El Niño, the periodic fluctuation in Earth's climate system that affects weather all over the world. It is thought to have got its name from Peruvian fishers, who named it "El Niño de Navidad" after the newborn Jesus Christ.

14. The place is the ear. Respectively, the clues describe a stirrup, anvil, drum and hammer. Three of these are the names of the bones – or ossicles – of the human ear, leaving the drum – or tympanic membrane – as the odd one out.

15. Astronaut. After leaving the moon's orbit on 25 December, Apollo 8 command module pilot Jim Lovell radioed confirmation to NASA's mission control that the crew members were on their way home and, presumably, they had also caught a merry sight.

URI GOLMAN/NATUREPL.COM

Iceberg wranglers

At least three teams plan to tow icebergs to warmer climes in order to harvest them for drinking water. Is it a good idea? **Matthew H. Birkhold** investigates

EACH June, tourists flock to Newfoundland to catch a glimpse of icebergs. Sparkling as they twist in the frigid waves of the Labrador Sea, icebergs have become one of the Canadian island's most important industries, attracting more than 100,000 visitors a year. But not everyone is satisfied merely watching the behemoth blocks of frozen freshwater – Ed Kean tries to catch them.

He uses his large fishing boat to harvest icebergs, then melts them and sells the water. Many local people swear to its purity and delicious taste. Kean's mother won't drink anything else.

But Kean won't have the iceberg business to himself for much longer. For decades, there has been talk of towing icebergs from the poles to warmer climes to slake the thirst of increasingly parched communities around the world. Now, there are at least three outfits with plans to make it happen. Iceberg harvesting is a concept that has always intrigued me, so I set out to discover whether it is really feasible on a large scale, and whether it can be done safely, without damaging our planet.

Iceberg wrangling isn't as fanciful as it might sound. The UN predicts that, by 2030, half of the world's population will face severe water shortages. Yet, there is no absolute shortage of fresh water. It is just that around two-thirds of it is locked away in ice caps and glaciers, which produce tens of thousands of miraculous parcels of frozen fresh water every year and send them into the salty oceans.

I began my investigations by finding out how Kean works. He starts by identifying promising bergs using satellite maps. If they are grounded on the seabed and stable, he uses a crane to scoop up huge masses of ice and feed them into a grinder. At other times, he nets loose chunks, then winches them aboard and hacks them apart using an axe before shovelling the pieces into huge plastic storage containers to melt.

Kean has been at this since the 1990s. Some years, he produces more than 1 million litres of water and sells it to local businesses. East Coast Glow uses the water in its cosmetic products, Quidi Vidi Brewery uses it to make beer and Auk Island Winery blends iceberg water into its berry wines. Since icebergs calve from glaciers that were largely formed before human-made pollution choked our atmosphere, the water they contain is purportedly among the cleanest on Earth. "Icebergs," quips Kean, "taste like water should taste."

The idea of towing icebergs from the poles to other parts of the world is more outlandish, but it has a long history. The oceanographer John Dove Isaacs was one of the first to expound it in its modern form. In 1956, he suggested capturing an 8-million-tonne iceberg in the Southern Ocean and towing it to San Diego, California, in 200 days. Another early dreamer was Mohamed Al-Faisal, a member of the Saudi Arabian royal family who became known as "the water prince". In the 1970s, he concocted plans to tow an iceberg to the Arabian peninsula.

Over the years, iceberg-towing mania has waxed and waned, but now things may be at a tipping point. One notable proponent is Nick Sloane, a marine salvage engineer with a good dose of credibility as leader of the team that refloated the Costa Concordia, the vast cruise ship that struck a rock and partially sank in 2012. For the past few years, he has been working on a plan to tow icebergs to Cape Town, South Africa, which regularly experiences acute water shortages. Closer to the equator, the inventor Abdulla Al-Shehi plans to drag an iceberg to the United Arab Emirates as a source of drinking water. He also wants to use iceberg water to transform the country's red sands into a green oasis, and recently patented a sun-blocking shield to help protect what he believes will be a massive tourist attraction. Meanwhile, POLEWATER, a private company, is raising millions to tow an iceberg from Antarctica to warmer waters off the African coast and melt it into newly designed "water bags" to use as an emergency freshwater source in regions facing environmental disasters.

How to shift a berg

The first question these projects must confront is whether iceberg towing is physically feasible (before, for example, it melts). Here, prospects are looking good. Mariners already tow icebergs short distances to stop them colliding with oil rigs in the North Atlantic. The crews encircle the frozen targets with thousands of metres of ultra-high-strength polypropylene rope, closing the snare with a grapple and attaching a steel towing hawser to weigh down the rope. They have learned that it is essential to pull the berg at a point below its centre of mass, otherwise the force causes it to overturn.

It is also possible to move very big icebergs: in 2017, the Russian energy company Rosneft claimed to have towed one weighing 1 million tonnes. But when you tow, you must go slow. Vessels can travel at no more than 2 knots (a leisurely walking pace); higher speeds create vibrations that could fracture the ice and cause it to break apart or jolt off the securing ropes.

Towing long distances looks feasible too. Recently, Alan Condron at Woods Hole Oceanographic Institution in Massachusetts used a mathematical model to simulate icebergs being towed from Antarctica to Cape Town and the United Arab Emirates. Considering solar radiation, wave erosion and heat exchange between the ocean and iceberg, he calculated that an iceberg 300 metres long and 200 metres thick at the time of capture would reach Cape Town with enough bulk remaining to supply 2.4 million litres of water. That would meet the basic drinking water needs of some 700,000 people, or around one-fifth of the city's population, for one day.

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SIPA/SHUTTERSTOCK

JOHANNES EISELE/AFP VIA GETTY IMAGES

First identify your quarry (top) and net any loose ice chunks (middle). Then use a boat-mounted crane to chip away at the main berg (above)

> "Towing must proceed at no more than 2 knots, which is a leisurely walking pace"

Wrapping the berg in an insulating material would result in significantly more surviving. There could also be ways of making the towing easier, for example, releasing bergs into the clockwise-flowing Antarctic Circumpolar current and then, at the right moment, towing them into the northward-flowing Benguela current along the west coast of Africa.

Even if iceberg towing is possible, it still may not be a great idea due to its environmental consequences. After calving, an iceberg freshens the surrounding ocean water and releases nutrients such as nitrates, phosphates, iron and sulphur. The denser, saltier water nearby sinks and causes water to circulate, creating an upwelling current that brings more nutrient-rich water to the surface. A web of life then develops around, underneath and above the iceberg. Single-celled algae such as diatoms use these minerals and their photosynthesising power to generate energy and grow. Krill then feed on these phytoplankton and make homes in the cracks and crevices of the iceberg. Icefish, comb jellies and segmented worms live among the phytoplankton, too. And icebergs are also important for seabirds, penguins, seals, whales and polar bears. Depending on the size of the berg, the radius of enrichment can stretch for kilometres.

Relocating icebergs would destroy these ecosystems. It would also short-circuit the ability of icebergs to sequester carbon dioxide and require considerable amounts of energy. And it would have an impact on the warmer waters into which any berg were towed. Estimating what exactly would happen is tricky until we actually try it. Olav Orheim, a former director of the Norwegian Polar Institute, who is working with Sloane, is in favour of giving it a go. "We can better figure out the environmental consequences once we have actually accomplished the feat," he says. Others believe more research is required first, but most people I spoke to support the idea in principle because of its potential for good.

My investigations have convinced me that someone is going to try long-distance iceberg towing sooner or later. Personally, I am intrigued and only a little worried to see what happens. Ultimately, the impact of iceberg harvesting will depend on its scale and rate. Here, perhaps, we should take a lesson from history because all of us know that when human hubris meets an iceberg head on, the result can be disastrous. ∎

Matthew H. Birkhold practises lassoing ice cubes in the bath. His book *Chasing Icebergs* is out now

The many worlds of AI

How will the era of artificial intelligence pan out for its creators? **Michael Brooks** explores the possibilities

IF YOU ask the AI-powered chatbot ChatGPT what the rise of artificial intelligence means for humanity's future, it proffers a measured response, concluding that "the future of humanity with AI is not predetermined, and its impact will depend on how AI is developed, regulated, and integrated into various aspects of society".

Sensible stuff but, let's be honest, evasive. If you really want to get to grips with how the era of AI will pan out for us, you are better off asking Scott Aaronson and Boaz Barak, computer scientists at the University of Texas at Austin and Harvard University, respectively. They have already gone to the trouble of boiling down the lengthy discourse on the matter to a handful of outcomes – and given each a whimsical name. "Our goal was to map out the scenarios that people are currently talking about," says Aaronson.

Discussing it at length over dinner, they ended up convinced that just five future worlds cover all the possible endpoints of our development of AI. The pair then wrote a post on Aaronson's blog, hoping that "The five worlds of AI" would help people in the field talk meaningfully to each other about end goals and regulation. "We took a humorous tone, but we are serious about trying to ground the debate," says Barak.

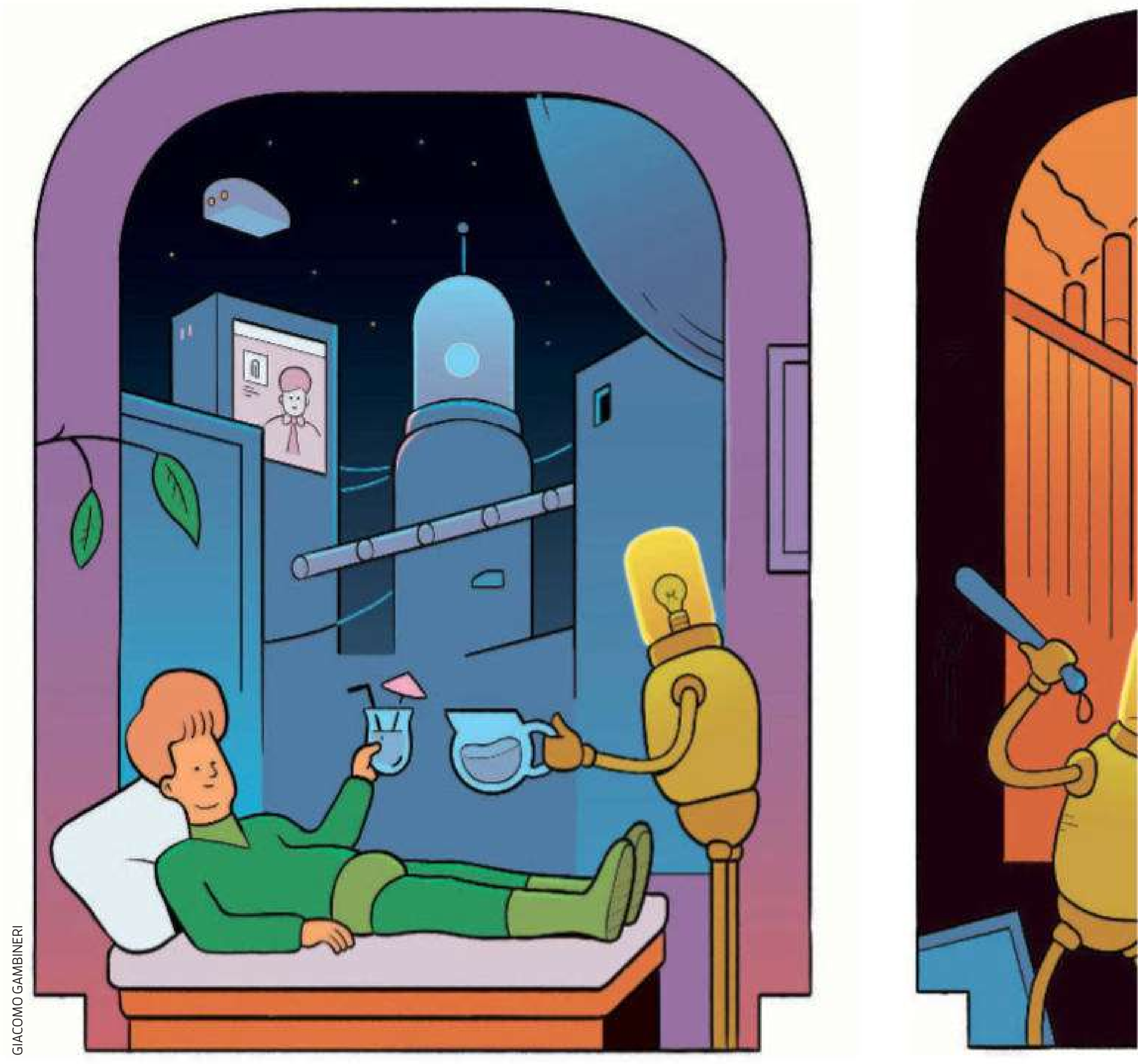
Here, then, is a vaguely choose-your-own-adventure style exploration of their five worlds. It is a bit of fun, with the twist that, depending on how we play things, we could wind up in an AI-assisted utopia…or wipe out humanity.

The journey to these five worlds begins with a simple question: will AI's potential fizzle away to nothing? It doesn't seem that way at the moment, but the march of AI could plausibly be halted by its voracious hunger for resources. It is possible that all the electricity and water needed to run and cool AI servers will eventually bring about a ban on further development. Or we might run out of data on which to train future AI models, meaning the technology will never achieve the game-changing power it promises, creating a world Aaronson and Barak call AI-Fizzle. "I think this scenario is unlikely," says Barak. "I believe that AI will change the world very significantly."

Assuming we don't end up in Fizzlandia, as one commentator described it, we have to face another question: does civilisation continue to develop in a recognisable way? If the answer is yes, Aaronson and Barak suggest we could end up in one of two further scenarios. One is good, and they call it Futurama after the animated TV series, which portrays a mostly positive future civilisation. The other, not so much. They call that AI-Dystopia.

AI-Dystopia is recognisable from countless science fiction stories, most famously George Orwell's *Nineteen Eighty-Four*. Here, a government uses deep surveillance to extract unquestioning compliance from its citizens. Inequalities and biases become entrenched, the workplace is miserable and employees are poorly paid, apart from a tiny elite. "People have said that the scenario of *Nineteen Eighty-Four* was never really feasible because you could never have enough people watching all of the screens," says Aaronson. "With AI, that becomes possible."

If we do arrive here, it won't actually be AI's fault, because powerful technology is only ever



GIACOMO GAMBINERI

an amplifier of existing issues, he says. "Some people would say that we shouldn't create a technology if we know that it is going to be used to do bad things. But if you're not going to invent anything that could be used for evil, you simply won't invent anything."

Barak is hoping that AI's development leads to the better, Futurama-style eventuality. This is the best of all possible worlds, in his opinion. "It's basically the scenario where things are like today, but better," he says. Here, AI is used to reduce poverty and ensure that more of humanity has access to food, healthcare, education and economic opportunities. There might be occasional harm, caused by human malice or negligence, but human inhabitants of this world are likely to be pretty pleased with their lot, overall.

And it could get even better than that. Aaronson is hoping that he might one day exist in an AI-led utopia that he and Barak call Singularia. This will happen if AI's impact is so profound that it renders our future world unrecognisable in a good way. Here, you will be living alongside AIs that are, effectively, a new super-intelligent species that takes over the running of civilisation. Luckily, they are benevolent gods, tolerant of the planet's poor, puny humans. They solve our material problems, providing us with unlimited abundance, taking on many of our humdrum tasks and providing entertainment for our newly understimulated minds. "It's effectively an AI-created heaven," says Aaronson.

Lovely. But what if the all-powerful AIs aren't so generous? Welcome to Paperclipalypse. There is a good reason for this world's odd name. In 2003, mathematician and ethicist Eliezer Yudkowsky, co-founder of the Machine Intelligence Research Institute (MIRI) in California, described a thought experiment where humanity tasks an AI with improving the production of some innocuous thing – paper clips, say. If the specifications aren't properly thought through, the AI could end up wiping out humanity because our species was standing in the way of harvesting all Earth's resources, and maybe those of other worlds, to make more and better paper clips.

Yudkowsky's argument was more nuanced than that, but the general point is simple: it isn't difficult to imagine scenarios where creating AI might be the last thing we humans do. Hence, there is a need to think hard about what AIs are allowed to work on, their connection to physical resources such as power stations or nuclear weapons, and the transparency and accountability of their developers. We need to think quickly, too. "It takes time to shift policy and regulation; the gears of government grind slowly," says Gretta Duleba, communications manager at MIRI. "We do worry that we will run out of time before meaningful legislation can be enacted."

Aaronson and Barak, for their part, aren't too worried about the prospects of a Paperclipalypse. While Yudkowsky sees a catastrophic event as the most probable outcome, almost a default, of poorly conceived AI research, Aaronson thinks this is unlikely. Barak is a bit more circumspect: "I am not a believer in highly extreme things like Singularia or Paperclipalypse, but I do think it's important to keep an open mind."

That seems like a good idea – mostly to make sure that we are careful about "how AI is developed, regulated, and integrated", as ChatGPT put it. If we aren't, we might find ourselves without any choice in how our choose-your-own-adventure with AI unfolds.

The truth is that even with well-intentioned regulation, it is entirely possible that we will end up in one of the AI-affected worlds we would rather avoid. In which case, we should also work out how to move between worlds. After all, we might someday want to find our way from AI-Dystopia to the Futurama scenario – or better still Singularia. "Do I want to live in a world with unbounded flourishing of sentient beings in whatever simulated paradise we want?" asks Aaronson. "Yeah, I'm pretty much in favour of that." ∎

ERNIE JANES/SHUTTERSTOCK

In one scenario, AIs wipe out humanity to make more paper clips

"AI's impact could be so profound that it renders our future world unrecognisable"

Michael Brooks, for one, is wary of our coming AI overlords

Inside the milk bank

The world's largest repository of animal milk is creating infant formula for some of the most endangered species. **Corryn Wetzel** finds out how

ROSHAN PATEL/SMITHSONIAN'S NATIONAL ZOO/CONSERVATION BIOLOGY INSTITUTE

ORCA milk smells dizzyingly fishy. Seal milk has a rich orange hue. Reindeer milk, perhaps fittingly, is as thick as eggnog. Not that I am tempted to try it, or any of the other unusual milks I can see stacked on shelves from floor to ceiling. I have donned a puffy winter jacket and stepped inside the freezer that houses the largest collection of animal milk in the world, containing that of everything from tree shrews to two-toed sloths and giant anteaters.

The collection, housed at Smithsonian's National Zoo in Washington DC, is more than a cabinet of curiosities – it is a critical resource for staff at this zoo and others around the world tasked with feeding orphaned infants. By studying all this white – and not-so-white – stuff, Smithsonian scientists can create custom infant formulas that will give the animals in their care the best possible start in life.

As their understanding of milk has improved, however, they have realised that their formulas are missing an important component: microbes. Now, as they explore the microbial diversity contained in different milks and the benefits these organisms bring, they are striving to replicate this in lab-made milk – not only to better assist young animals in the zoo, but also to aid the survival of some of the rarest species in the wild.

"The objective isn't necessarily to freeze milk, archive it and not touch it," says Pierre Comizzoli, who leads the Smithsonian's cryopreservation initiative. "It's to use it to understand and sustain biodiversity."

Milk is the essential first food for mammals. From mice and marmosets to humans, mammals are born incapable of feeding themselves. By producing milk, mothers can give their offspring the key nutrients they need to develop and grow.

Here at the milk bank, researchers have collected over 16,000 samples from more than 200 species – around 3 per cent of the roughly 6000 mammal species in the world. New samples are constantly being added, many from animals kept at the Smithsonian zoo, but also from other zoos and conservation organisations. Some animals can be milked by hand – including a cheetah called Izzy, trained to be milked using a handheld pump – while other samples are collected when an animal is under anaesthesia for a medical procedure. "As long as the sample is good quality and taken ethically, we're not picky – we accept everything," says Comizzoli.

The result is a collection that illustrates the diversity of mammalian milk. Looking at the colours and consistencies of the samples in the freezer, it is striking just how different they are – the milk of each species is the result of millions of years of evolutionary adaptations.

High-energy hit

Take howler monkeys, which have milk that is around 1 per cent fat. "If you nurse your baby frequently, which primates do, you can afford to have a fairly dilute milk," says Michael Power, curator of the milk repository. Tree shrews, by contrast, produce milk that is around one-third fat and "oozes like butter", says Power, because they only visit their offspring for 10 minutes every two days to nurse them. This strategy avoids drawing predators' attention to the nest of infants, but it means mothers need to pack lots of fat – and hence energy – into a small amount of milk.

Understanding these differences is vital when it comes to looking after orphaned infants or those that aren't thriving. This is where the milk bank comes in. When screaming hairy armadillo pup Sherman

TUI DE ROY/NATURE PICTURE LIBRARY/ALAMY

ESPEN BERGERSEN/NPL/ALAMY

Top: Poaching leaves black rhino orphans. Bottom: Orca milk smells fishy

CORRYN WETZEL

Far left: Sherman the screaming hairy armadillo pup being fed formula. Left: Hannah Shinnerl holds frozen milk samples

wasn't growing after his mother stopped producing milk, for example, zookeepers knew the few commercially available infant formulas, for common species such as dogs, cats, sheep and cows, wouldn't be right for him. Instead, they turned to the milk bank for a custom formula.

The nutritionists and vets at the bank usually begin by thawing one of the frozen milk samples, some of which date back decades. They then separate each sample – which can be as small as 5 millilitres – into its components like fat, protein and sugar. They also look at minerals in the milk, mainly calcium and phosphorus.

Their analyses of armadillo milk revealed it has an "astronomical level of calcium", needed to build the animals' bony carapaces, says Smithsonian clinical nutritionist Erin Kendrick. It also has a higher-than-usual level of protein, to increase calcium absorption.

Once the researchers know what they are aiming for, they turn to the commercial formulas, tinkering with them until they create the closest match. The whole process can take a matter of days and, in the case of Sherman, it did the trick. When I stopped by the zoo's small mammal house to see the now adult armadillo, he was blissfully scavenging for mealworms.

There are occasional mishaps, however, says lab technician Hannah Shinnerl. When mixing seal milk, she once stirred it for too long and "accidentally made seal butter" and had to start again. On the day I was visiting, she was in the process of separating casein proteins from tapir milk. The result might best be described as tapir cheese, with a ricotta-like consistency.

But milk is more than just the sum of its proteins and minerals – it also contains bacteria. "Every animal has a microbiome, so every animal that produces the milk is going to have microbes in their milk," says Sally Bornbusch, a microbial ecologist at the zoo.

> **"Tree shrews produce milk that is around one-third fat and oozes like butter"**

To find out more about this microbiome, Bornbusch, Power and their colleagues looked at the milks of 47 mammal species, from giraffes to wolves, and compared the microbes they harboured. They found that closely related species were more likely to have similar microbes, but diet and habitat also played a role. "What that implies to me is that the microbes that get into that milk are not just random," says Power. Indeed, they play many important roles, including building an infant's immune defences. "Those incoming microbes from mom's milk start to train the infant's immune system by teaching it what to tolerate in terms of bacteria, and [what] not to tolerate," says Bornbusch.

But she says it is too soon to start adding specific microbes to batches of formula, as we don't want to accidentally introduce harmful bacteria. In cases where an infant's gut needs to be seeded with microbes, the researchers whip up what they call a "poop milkshake" – blending its infant formula with its mother's faeces. "We try and get all of those microbes that mom has into the baby to help spark their microbiome," says Bornbusch. The technique worked for Vlad, a young two-toed sloth at the zoo who wasn't growing as quickly as expected. He began putting on weight after drinking the milkshake.

With orphans, however, the researchers lack the mother's faeces and so can't make a poop milkshake. This is a particular problem in species where poaching has left many in need of formula, such as the critically endangered black rhino. The team is now working on how to seed infant formula for black rhinos with microbes, says Bornbusch, which may help them digest their starchy diet. She expects microbe-rich rhino formula will be available within the next few years, and the recipes will be shared with partners abroad in order to help as many youngsters as possible. Hopefully they, too, will soon get a better start in life. ■

Corryn Wetzel's favourite milks are oat, soya and orca

Doomsday revisited

The first sightings of planets that seem to have miraculously survived the death of their stars is forcing a rethink of Earth's fate, says **Stuart Clark**

LUONGDOO

IT ALL seemed so simple when we knew the date of Earth's demise. In 5 billion years from now, so the story went, the solar system will have dramatically transformed. Instead of being the benign presence we are used to, the sun will have ballooned into a giant, hundreds of times bigger than it is today. In the process, it will wipe out the rocky, inner planets, including our own.

Or will it? We have recently caught sight of the dying stages of other stars for the first time. And, miraculously, some planets seem to be able to survive these apocalyptic periods. Such observations are challenging the story of how Earth will die and giving us hope that it might somehow outlast the sun. Even if it doesn't, all is not lost. The research is also giving us clues to where humanity could best take refuge.

The sun is powered by nuclear fusion, in which hydrogen atoms are melded together into helium, releasing vast amounts of energy in the process. But our star's fate is sealed by one fact: it has a finite supply of hydrogen. As this begins to run out – in about another 5 billion years – the sun's internal structure will change and it will expand to around 200 times its present size. It will transform from the yellow dwarf it is today into a red giant. After a further billion years or so, and another round of shrinking and ballooning, it will then die and shrink back down into a stellar corpse called a white dwarf.

As it grows to become a red giant, the sun will get hotter as the nuclear reactions inside its core creep outwards to find fresh sources of hydrogen fuel, closer to the sun's surface. In about a billion years from now, we think this will make the surface temperature on Earth hot enough to boil away the oceans, leaving the planet covered in salt flats and dunes. Without water, plate tectonics will stop and at a certain point it will be hot enough to melt rock.

If humans are still around at this point, we may struggle to survive much longer, as there is, unfortunately, worse to come. As the sun grows, first Mercury, and then Venus, will be engulfed by it. Their outer layers will evaporate and the remaining cinders will spiral down into the fiery depths of the sun. Estimates suggest the red giant's surface will eventually be within touching distance of Earth's current orbit. So if it isn't subsumed into the sun, Earth will still be fried beyond recognition.

In March this year, Kishalay De at the Massachusetts Institute of Technology and his colleagues spotted this gruesome process in action for the first time. They found a star around 13,000 light years away that brightened by a factor of 100 over 10 days, indicating it had gobbled up a planet some 30 times larger than Earth.

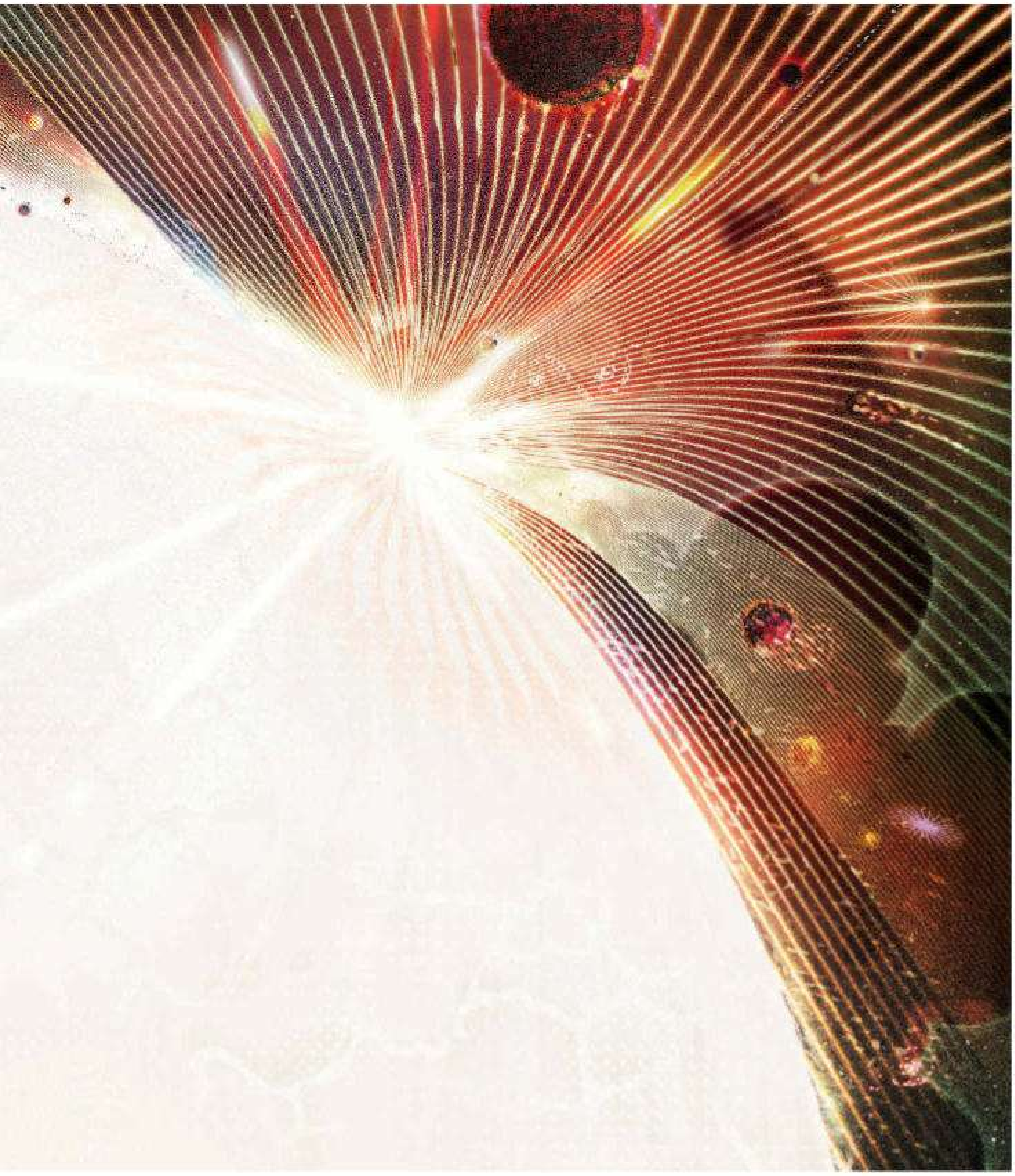
Escape to Jupiter

Thankfully, astronomers have an escape plan for humanity. While the inner solar system will become utterly hellish, its currently frigid outer reaches will warm up. "When the sun becomes a red giant, the zone of habitability will extend further," says Rafael Luque, an astronomer at the University of Chicago. "We know there is a lot of water in the moons of Jupiter and Saturn, so there could be a second generation of habitability within our solar system."

We have solid evidence that gas giants akin to Jupiter can survive their parent star's death. In 2021, such a planet was observed in orbit around a white dwarf near the centre of our Milky Way galaxy. Astronomers could tell that the star and this planet had formed at around the same time, meaning this world survived not only the star's red giant phase, but also its dramatic death, when it completely shed the outer layers of its atmosphere and collapsed to become a white dwarf.

This survivor sits further from its star than Earth is from the sun, around 2.8 times the distance. Its existence suggests that we could indeed take refuge on the moons of a gas giant in our own cosmic backyard. Jupiter is 5.2 times Earth's distance from the sun. If that proves too hot, Saturn is nearly twice as far away.

However, there is a chance we won't need to take such drastic measures. Earth might just survive the sun becoming a red giant. Shreyas Vissapragada at the Harvard-Smithsonian Center for Astrophysics in Massachusetts suggests that it might be pushed outwards by the expanding sun's solar wind, which



> **“If Earth isn’t subsumed into the sun, it will still be fried beyond recognition”**

would have been strengthened as it swelled into a red giant. Even if the solar wind doesn’t come to our rescue, there is still hope – at least, that is what the discovery of a planet, known as 8 Ursae Minoris b, or Halla, suggests. This world was discovered in 2015. At first, it appeared to be a common-or-garden “hot Jupiter”, a gas giant orbiting close to its star, known as Baekdu. There was just one problem. “This planet should not exist today,” says Marc Hon at the University of Hawai’i at Mānoa.

Hon came to this remarkable conclusion in early 2023. By looking at the way the surface of Baekdu is oscillating, his team concluded that this star must be at an advanced stage of its evolution. Deep inside, it must be generating energy by fusing helium into carbon, instead of hydrogen into helium, as is happening inside our sun. This means that Baekdu has already gone through its red giant stage. By everything we thought we knew, Halla should have been engulfed long ago, burned to a crisp and otherwise evaporated away.

“This is the first system that we know of in which a planet survives so closely around a giant star that burns helium in its core,” says Hon. “From our understanding of how ordinary giant stars evolve, they begin burning helium only after they have swelled up to an immense size, and this swelling should have consumed this planet.” Exactly how Halla escaped destruction is unclear.

Even if Earth survives our sun’s red giant phase and ends up orbiting a white dwarf, we may still not be safe. In November 2022, Abbigail Elms at the University of Warwick, UK, and her colleagues discovered a white dwarf system 90 light years away littered with the remnants of dead planets. “By observing white dwarfs, we can conclude what the planet was made from,” says Elms. It looks like this graveyard is likely polluted by the debris of Earth-like planets, with traces of sodium, lithium, potassium and carbon.

If these planets survived the star’s red giant phase, they may then have met a grisly fate. White dwarfs have roughly the mass of the sun packed into a volume smaller than that of Earth and this gives them extremely strong surface gravity. This creates such extreme tidal forces on any nearby surviving planets that they can be literally pulled apart. The orbiting material then spirals onto the white dwarf. If this fate befalls our home world, it would mean it has pluckily avoided death by fire, only to be pulled limb from limb.

However we look at it, if humankind sticks around for the next few billion years or so, it is highly likely that we will have to migrate from our planet. But the real kick in the teeth is that we probably won’t be able to go directly to Jupiter’s moons for refuge. They won’t be warm enough until the sun is a complete red giant, but we will surely have to abandon spaceship Earth way before that.

So if we have to evacuate, and Jupiter isn’t yet hot enough for its moons to become habitable, what do we do? At one and a half times further from the sun than the Earth, Mars could look very attractive indeed. It might buy us a few billion years or so, anyway. ■

Stuart Clark is making plans to escape to Mars

Cocktail physics

These four delicious drinks show off the wonders of fluid dynamics, says **Karmela Padavic-Callaghan**

YOU may think that complex equations and alcohol don't, or perhaps shouldn't, mix. But make your favourite cocktail and you will unknowingly encounter some of the most complex processes in fluid dynamics, the study of how liquids flow.

When researchers try to predict how a fluid will move, bubble or create waves, they often run into complicated equations. The starting point for solving almost any of these problems is the Navier-Stokes equations, named after Claude-Louis Navier and George Gabriel Stokes. The pair devised them in the 1800s, which also happens to have been the golden age of mixology.

What better way, then, to learn about fluid dynamics than by indulging in some cocktails? Whether it is how foams are made, the formation of unusual clouds or liquids spurting at supersonic speeds, some wonderful surprises can hide in a drink. Roll up your sleeves and dig out your cocktail shaker!

GIN FIZZ

Experience the miniature marvel of foams

First up, something fizzy. Made from two parts gin, one part lemon juice, a dash of syrup and a splash of soda water, the gin fizz would be simple were it not for its layer of foam.

Foams challenge physicists. At times, they behave like solids; at other times, they act like liquids. Soapy bubbles flow like water when you wash your dishes, but the stiff head of a beer can be sliced off in one.

This difference comes down to the bubbles. When bubbles crowd together, they make a foam. But how foam acts depends on the molecules inside the bubbles' fluid casing. Foamy beers and the frothy milk that tops a cappuccino, for instance, are full of proteins, as is the egg white that traditionally makes the foam in a gin fizz.

STOCKFOOD/BLUME, JENNIFER

Protein molecules are slightly electrically charged and have both water-loving and water-repelling parts. These properties cause them to align in just the right way to keep bubbles from collapsing – for a while, at least. Stronger attractions between the protein molecules, and a high concentration of them, result in stiffer foams that behave more like solids. Foams with fewer molecules or molecules that barely interact stay runnier.

For a gin fizz, we need our foam to be robust so that it sits on the top of the drink. If you whisk the egg whites vigorously enough, the proteins will stretch out, then link up, leaving you with the perfect pourable foam. If you prefer not to use egg whites, the liquid from a can of chickpeas, known as aquafaba, is a good alternative as it is chock-full of proteins. And if you are struggling to make a foam, adding a bit of cream of tartar will nudge the proteins to stretch more reliably and quickly.

B-52

Create a complex cloud in your glass

The physics, and the flavours, get more complex when you pour a drink with more than two layers. Take the eye-catching B-52. This short cocktail contains equal amounts of three alcoholic beverages: a layer of orangey-gold Grand Marnier sits on top of milky Irish cream, which floats on a deep brown coffee liqueur. And with this cocktail, we can demonstrate something called the Kelvin-Helmholtz instability.

The drink's layers stay separate within the glass because each is less dense than the one below. Buoyant forces, caused by the pressure on the molecules at the bottom of each layer being larger than the pressure on the molecules at the top of each layer, counter gravity's downward pull. Bartenders pour B-52s one liquid at a time, slowly over the back of a spoon to avoid mixing.

ALEX OVERHISER

PAVEL/SHUTTERSTOCK

LAURIPATTERSON/GETTY IMAGES

A rum punch (far left), gin fizz (top), French 75 (left) and B-52 (above)

Earth's atmosphere and oceans also contain layers of clouds and layers of water of different density, temperature and salinity, respectively. And when two stacked layers of fluid move over each other, be it water or liqueur, spectacularly wispy clouds can arise.

The Kelvin-Helmholtz instability kicks in when the forces of one layer dragging over another overwhelm the buoyant forces that keep them apart. As the buoyant forces start to lose the fight, the top layer of fluid doesn't immediately sink into the one below it all at once. Instead, parts of it descend in the form of swoopy, cloud-like structures.

In the atmosphere, the Kelvin-Helmholtz instability causes fluctus clouds that look like breaking ocean waves, but the same physics hides within a glass of B-52. Tilt your glass, or give it a spin, and you might see tiny, wispy clouds appear. But be gentle – if you use too much force, you will be left with a delicious beige mess.

FRENCH 75

What really happens when champagne pops

The French 75, as well as being tasty, calls for an especially dramatic ingredient. A mix of gin, lemon juice, syrup and some champagne, all the action happens before you pour this drink, in the explosive uncorking of a bottle.

When champagne ferments, yeasts eat up the sugar in grape juice and produce carbon dioxide, giving the drink its fizz. But this also creates pressure inside the champagne bottle meaning that, when you uncork it, jets of carbon dioxide come rushing out.

In 2019, Robert Georges at the University of Rennes 1 in France and his colleagues used a high-speed camera to capture the details of a champagne bottle uncorking. They found that in the first millisecond of the process, the jets achieve supersonic speeds. The fastest they identified went flying at about four times the speed of a Formula 1 car.

The researchers then simulated this process in detail on a computer, which required solving some equations formulated by Navier and Stokes. They found that the gas forms shock waves of various shapes behind the cork, first resembling a crown while stuck behind the slower-moving cork, then forming a foamy cylinder, then finally slowing down and running along the sides of the bottle.

Georges refers to a bottle of champagne as a "mini laboratory for the physics of fluids". But past those first few milliseconds, the only experimentation left for you will lie in deciding whether to swap the syrup in your French 75 for a sugar cube.

> **"A bottle of champagne is a mini laboratory for the physics of fluids"**

RUM PUNCH

Sail a boat on top of your tipple

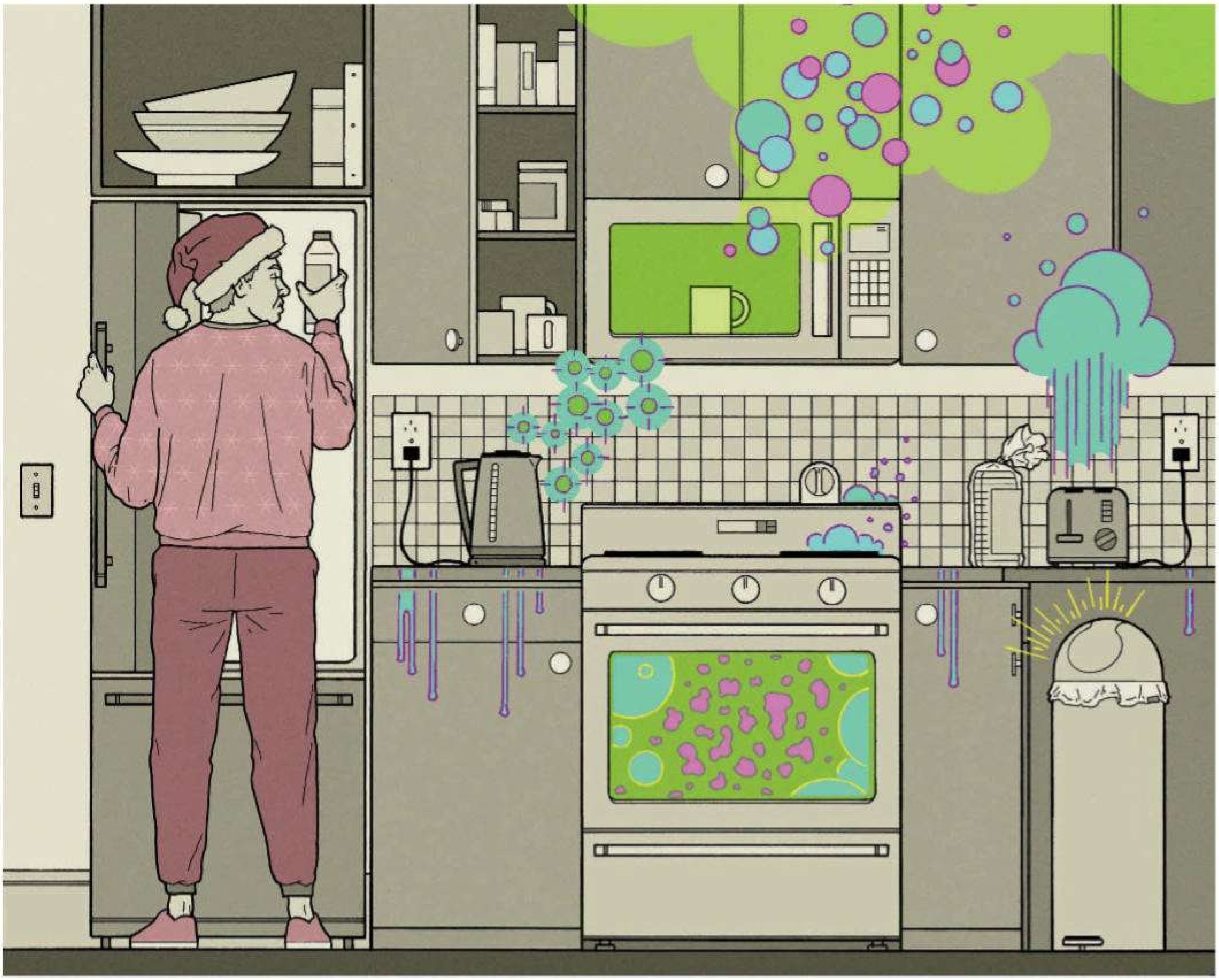
You can have a lot of fun with a rum punch if you know this secret. But first, let's mix one up. The traditional recipe calls for rum and fruit juices mixed with some sugar syrup, grenadine and Angostura bitters. Now you have your drink, you are ready to experience the power of a phenomenon called the Marangoni effect.

The curious result of a difference in surface tension, this effect was amusingly demonstrated in 2013 by John Bush at the Massachusetts Institute of Technology and his colleagues. In collaboration with professional chefs, they created a small fleet of miniature boats from ingredients like gelatine, agar and melted candies. They 3D-printed silicone moulds, then poured the edible mixture into them to cast tiny vessels with a slit in the back. Then, they set these on rum-powered journeys across cocktail glasses.

Each boat was filled with rum that slowly leaked from the slit at its stern. When rum mixed with the liquid in the glass (which, in the experiment, was water rather than fruit punch), it made the surface tension lower at the boat's stern than at its bow. Water molecules started to move from the back to the front of the boat in an effort to even out the tension, propelling it in the process. This is the Marangoni effect.

In the team's experiments, the 1.5-centimetre-long boats travelled as fast as 11 centimetres per second. You can try it with fruit juice, effectively preparing your own rum punch as the boat sails. Perhaps there is also an optimum number of cocktails to be consumed before beginning the experiment. Something else to try out over the festive period? ∎

Karmela Padavic-Callaghan is ready for the holidays to be-gin



KYLE ELLINGSON

What's living in your kitchen?

Bizarre microbes inhabit the extreme conditions inside your domestic appliances. **Claire Ainsworth** hunts them down

"CAN I ask what all this is for?" The pharmacy assistant is eyeing me suspiciously. I have just asked for some covid tests, urine sample pots and sterile scalpel blades. Oh, and some latex gloves, please. "I want to see if there are extreme life forms hiding in my dishwasher," I explain. "I see," she says carefully, before scurrying off to consult a colleague.

It is an unusual shopping list, I'll admit. To explain it, I need to rewind to June, when I spotted a study about bacteria that can live in what humans consider to be extreme conditions, such as high temperatures, caustic liquids or intense radiation. Normally, scientists head to exotic locations to find these microbes, such as the scalding volcanic springs of Yellowstone National Park or the frozen

deserts of Antarctica. But you don't have to go to the ends of the earth to find them, this study said. Chances are, extreme-loving microbes are not only surviving, but thriving, in the appliances in your kitchen.

> **"I had to find out if my kitchen was home to microbes with superpowers"**

That was it. I had to find out whether my kitchen really was home to microbes whose adaptations are like a list of superhero powers. In the process, I gained a new appreciation of the diversity of life – and won't see my coffee machine in quite the same way again.

Extreme-loving microbes are a goldmine for bioprospectors who pan the natural world for biotechnology innovations. Covid PCR tests, for example, rely on a DNA-copying enzyme first isolated from a bacterium called *Thermus aquaticus* that lives in hot springs, tolerating temperatures hot enough to poach an egg.

As well as surviving extremes of heat, microbes can thrive in bitter cold – even living in ice and snow. Some flourish in high salt concentrations, others in rivers as acidic as your stomach. A few hardy ones can even resist radiation and desiccation. You might think it impossible for any organism to survive such conditions, says Manuel Porcar at the University of Valencia in Spain, yet these microbes show it is indeed possible.

There are extreme environments in your home, too. Temperature-wise, many houses are kept at around 20°C (68°F). But our kitchens contain appliances that run much hotter: 70 or 80°C (176°F) or more. Some operate using harsh chemicals. "So from an ecological perspective, they are closer to Yellowstone than to your bedroom," says Porcar.

Coffee machine denizens

And in them is life. Over the years, researchers have found "extremophile" microbes in appliances such as hot water tanks, washing machines and dishwashers. Even your coffee machine has its inhabitants. "It's like a world in itself, with different cycles of temperature and caffeine," says Porcar. His team has shown how a microbial community adapted to life in the hot fluid of a coffee machine drip tray can form. In theory, microbes could even cling to life in your microwave oven, enduring repeated pulses of microwave radiation, desiccation and heat.

Which begs the question: how did they get there? Many microbes are great travellers, borne around the world by wind and water. They can settle anywhere, but only thrive where the environment is right for each particular species. It is well known in microbial ecology circles that "everything is everywhere, but the environment selects". In other words, the microbes you find thriving in a given spot tend to be influenced less by geography and more by the particular conditions of that environment.

Intriguingly, this also holds for human-made habitats. Porcar and his team have shown that not only can certain microbes survive on the desert-like surfaces of solar panels, but the communities you find there are the same on panels in locations as different as Spain, California and the north and south poles. This insight led them to suggest the concept of the Microbiome of Things, the idea that appliances around the world share common selection pressures. So, the microbiome of a microwave oven or dishwasher in the UK should be similar to that of one in Australia, Canada or even an Antarctic base.

Eaten up with curiosity as to what might be living in my kitchen, I contacted Porcar, who also heads a bioprospecting company called Darwin Bioprospecting Excellence. He and his colleague Adriel Latorre agreed to analyse samples from my kitchen. This was easier said than done, as I didn't have the usual lab equipment. But a trip to the pharmacy and one startled assistant later, I had what I needed.

The covid tests supplied sterile solution and swabs that I used to takes samples. Anything that looked like a microbial film, I scraped off with a scalpel and put in the urine pots. I then froze everything, couriered it to Spain and crossed my fingers that we would find something interesting.

After a nail-biting few weeks of waiting, the results from my kitchen are in. The Darwin team successfully extracted DNA from the samples and sequenced parts of a gene called 16S rRNA, which allows bacteria to be identified down to the level of their genus. This won't allow us to unequivocally prove the presence of a specific extremophilic species – that would involve prolonged, expensive experimental tests – but the analysis gives a pretty strong steer, says Latorre.

The appliance that topped the list in terms of the total number of different microbes was my dishwasher, which hosted 70 genera, or groups, of bacteria. This machine subjects its microbial denizens to 65°C (149°F) heat, water stress, detergent, dishwasher salt and dry periods, and was the main source of heat-loving or heat-tolerant bacteria in my kitchen. These include *Exiguobacterium*, a genus containing many extremophilic species that grow in a range of harsh environments, including hot springs, glaciers and salt lakes, *Priestia*, which can form spores highly resistant to heat, and *Paracoccus*, which has been found in hot springs. There was biotech potential there too: *Bacillus*, a genus that promises applications such as antimicrobial compounds and heat-stable enzymes needed by the detergent industry, and *Acinetobacter*, which includes the bioremediation of heavy metals and fuel spills among its many talents.

Next up is my coffee machine, home to 53 unique genera. The most abundant, *Methylobacterium-Methylorubrum*, contains species known to metabolise caffeine, as do two other genera found alongside it, *Acinetobacter* and *Pseudomonas*. Fermenting coffee beans with microbes like these could be a new and improved way of producing decaffeinated coffee.

Bringing up the rear is my washing machine (not strictly a kitchen appliance, I know, but it does create extreme conditions within the home) with six detected genera, including some, such as *Pseudomonas putida*, known to break down pollutants and organic molecules.

Are these results surprising? "Yes and no," says Porcar. The microbial diversity found in my appliances is consistent with previous studies, but there are intriguing findings, such as *Methylobacterium-Methylorubrum* being the most abundant genus in my coffee machine, which is not what Porcar's previous studies have found. The team might try to grow it in their lab to find out more about it.

For me, the experiment highlights the astonishing versatility of life and how much there is yet to be discovered in unexpected places.

Now then, who's for coffee? ▮

Claire Ainsworth will take any opportunity to write about interesting cultures

A very modern medieval map

Overlooked for centuries, the Fra Mauro map kick-started the science of cartography, says anthropologist **Meredith F. Small**

DURING a stay in Venice a few years ago, I spent time in the Correr Museum, soaking up the city's history. Located in Saint Mark's Square, the museum displays imposing statues, paintings of sea battles and ancient weapons. But as I passed through the last room of exhibits, another artefact hanging alone in an alcove caught my eye. It was a map of the world – a "mappa mundi" in Latin – but it was unlike any I had encountered before.

Framed in gold and 2.4 metres in diameter, the world pictured here was a combination of rolling blue seas with cresting waves and off-white landmasses, all covered with handwritten notes. It was one of the most beautiful, and beautifully complex, things that I had ever seen.

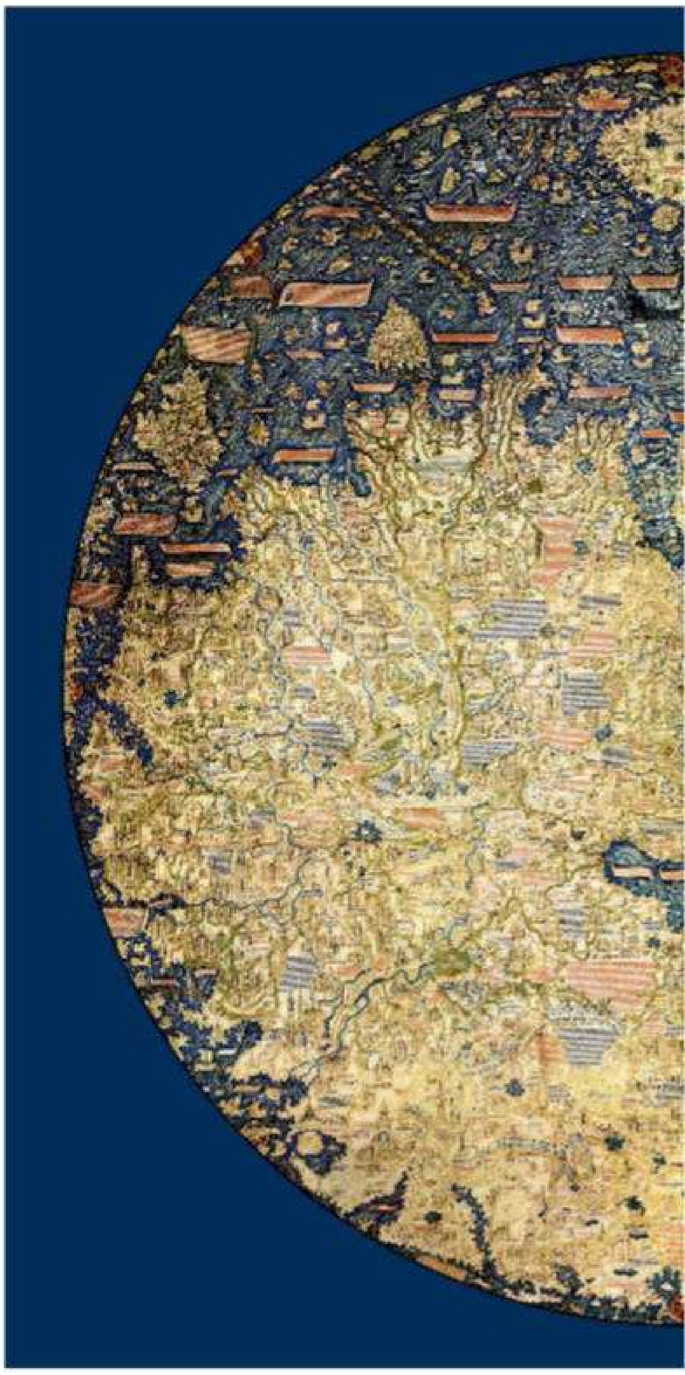
Created by a monk called Fra Mauro 550 years ago, the map had been largely overlooked for centuries, a lamentable state of affairs considering it displays a level of accuracy absent in earlier maps. Turn it upside down – Mauro placed south at the top – and it is recognisable as a map of Africa and Eurasia.

Following my visit to Venice, I decided to find out more about this map, a project that culminated in my book *Here Begins the Dark Sea*. I spent more than a year delving into the literature on world maps, poring over Fra Mauro's creation and trying to understand what he intended it to say. It turns out that it was part of the inflection point from the Middle Ages to the Renaissance because it was the first world map based on science and geography rather than religion. As such, it initiated the discipline of cartography.

Fra Mauro was a lay monk of the Camaldolese order living on the monastery island of San Michele just off the northern edge of Venice, which, at the time, was the world's most important trading hub. He was commissioned by the Venetian government to make his map, which took him nine years, even with the help of a team of artists and calligraphers. We know little about his qualifications as a map-maker, only that he did some survey work on behalf of the monastery and had been hired to help with a project rerouting a river away from the Venetian Lagoon. All his geographic work on the map was informed by past maps and visitors to Venice, including sailors and traders.

In 15th century Europe, world maps were usually full of images of Christ and biblically important places, and imbued with warnings of death at the hands of barbaric hordes. Monsters inhabited their geographic unknowns. Fra Mauro rejected those conventions. For example, he didn't centre the map on Jerusalem, as was usual at this time; he reduced the Holy Land to its correct size; and Noah's Ark is just a tiny house atop a mountain. Nor did he include any monsters, although he did mention those stories within the map's inscriptions – before dismissing them. He still showed the Garden of Eden and his take on the cosmos, but he placed these images off the map, separated from it by a large, golden frame, making them officially otherworldly.

Fra Mauro also made a major geographic decision that rocked the world of international trade. He was the first cartographer to show definitively that ships could sail around the southern tip of Africa, which made trade with Asia and the Spice Islands more efficient and cheaper than was the case with the combination of land and sea routes used at the time. That also meant people in Europe had to accept that the Indian "Sea" was an ocean, rather than an enclosed body of water. He was



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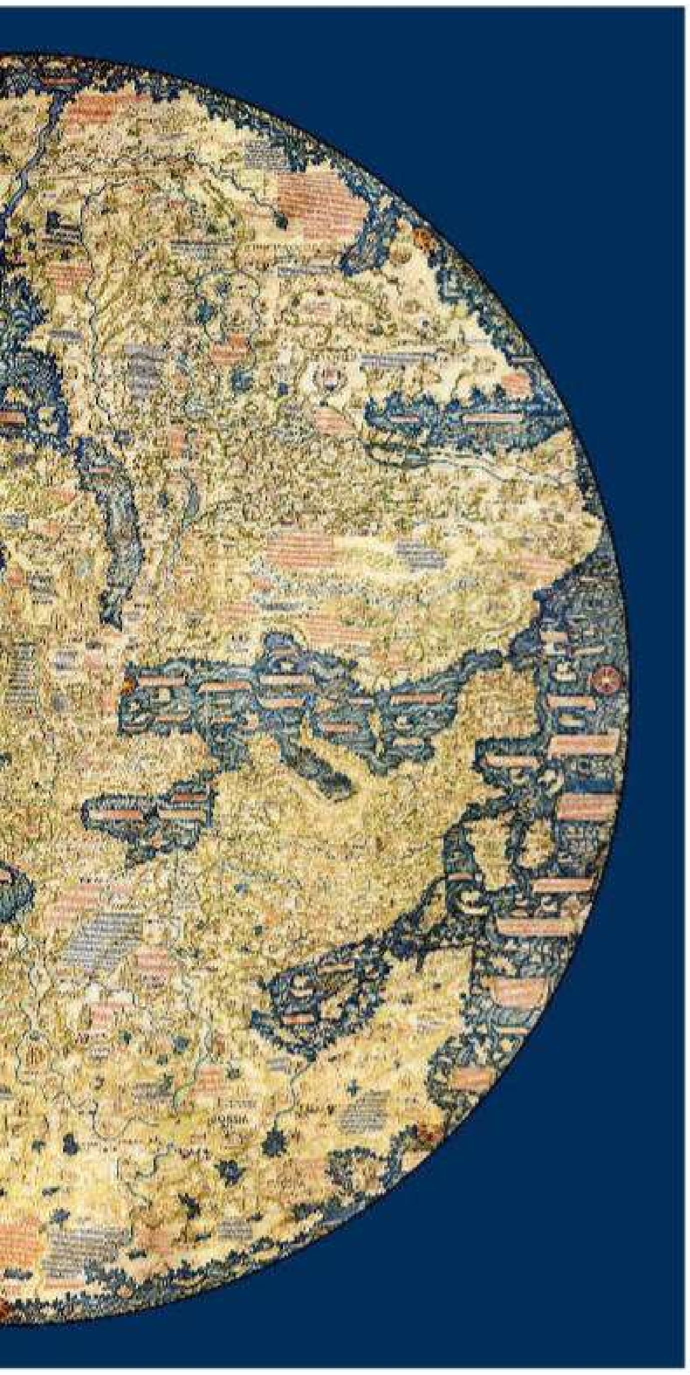
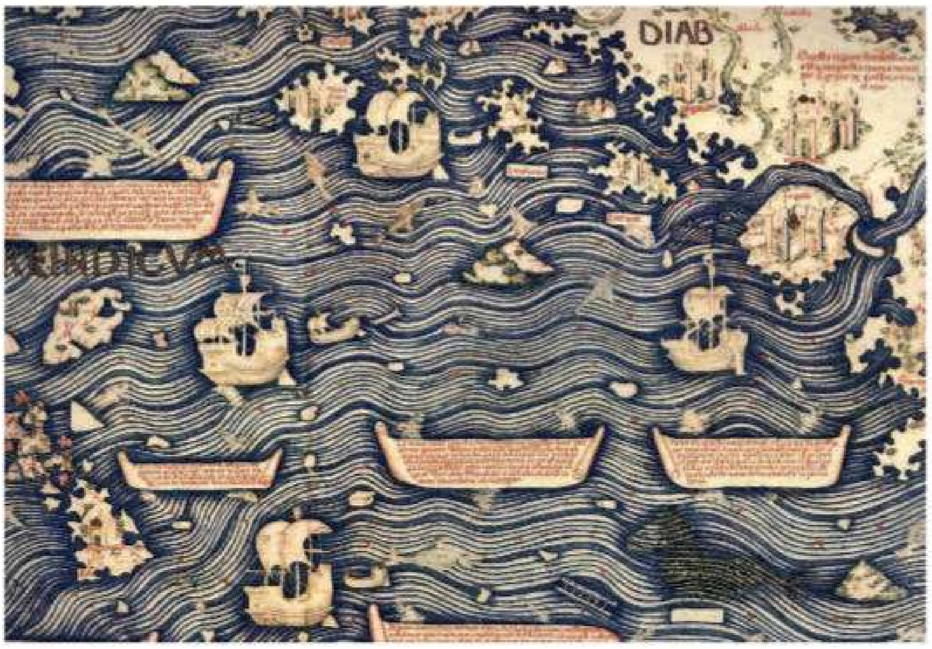
> **"Fra Mauro's map was an attempt to represent the world more truthfully"**





YOGI BLACK/ALAMY

Fra Mauro's beautiful, intricate map of the world (far left). Close up, inscriptions (left) explain the evidence behind his design

also the first European cartographer to place Japan on a world map. Of course, he had no idea of the existence of the Americas, Australia and Antarctica, but his geography of the then-known world is surprisingly accurate.

Yet Fra Mauro's creation is so much more than a map. It is also a medieval encyclopaedia, intended as a conversation with the viewer. It is festooned with more than 3000 inscriptions written in Veneziano, the language of Venice, rather than the more traditional Latin, suggesting Fra Mauro wanted to communicate with everyone, not just the intellectual elite.

The range of topics in the inscriptions is extensive and informative. For example, he uses the words of Marco Polo and other traders and adventurers to describe the lifestyles, belief systems and physical features of peoples in Africa, South-East Asia and the far north of the Atlantic as well as northern Russia. Being Venetian, it was also natural for him to point out where to find trade goods and natural resources, such as gold, gems, animals, cloth, spices and all sorts of edible items. He underscored the international nature of this trade by drawing various types of boat floating on the seas, from Chinese junks to Arabian dhows. Line by line, Fra Mauro is explaining to the viewer that it is a big, wide world out there and not everyone looks or acts like people in Europe. He was acting as a medieval anthropologist.

Fra Mauro was also prepared to reject received wisdom if it clashed with more recent observations, unlike previous scholars who typically accepted without question the works of ancient writers like 2nd century AD polymath Ptolemy. And like modern scientists, he sometimes changed his mind – some of his inscriptions are glued on, like Post-it notes, covering up past knowledge that was no longer deemed accurate or relevant.

He also noted where he obtained his information, often relying on conversations with sailors and foreign visitors to Venice. Such explanatory inscriptions rarely appear on other medieval world maps, and never to this extent. Fra Mauro's map, although a fine work of art, is also a visual and verbal defence of a point of view that was based on known geography. As such, he initiated the science of cartography based on direct observations by travellers and explorers, not beliefs.

In that sense, Fra Mauro's map was an effort to represent the world more truthfully, something cartographers still struggle with today. Even though we now have clear pictures of our world taken from space, there remains the frustrating issue of projection: how to peel off the skin of the globe and flatten it out onto a 2D surface without distorting the geography.

Ptolemy first wrestled with this problem by advocating for lines of latitude and longitude as a grid curved into the shape of a cloak to keep landmasses in their correct relative position. Map-makers after Fra Mauro chose other types of projection, such as the cordiform or heart-shaped projection with curving longitudinal lines, or the cone shape projection with a polar orientation. But these both distort landmasses.

Such distortions can, intentionally or not, carry political messages. The Mercator projection, for example, stretches the landmasses nearer the poles and so makes some countries – those of northern Europe, for instance – look larger than they really are. Many observers have noted that this can overstate the importance of such countries.

A new world map published in 2021 by physicists J. Richard Gott, David Goldberg and Bob Vanderbei minimised such distortions. In fact, they argue it is the truest flat projection of the world yet produced. It comes in the form of two discs representing the southern and northern hemispheres, glued together to create a two-sided map.

It is unlikely that this will be the final word. It seems we never stop fiddling with world maps. That is why there is a reproduction of Fra Mauro's map hanging on my wall: to honour our cartographic past and acknowledge our ongoing attempts to fully understand who we are and where we live. ▮

Meredith F. Small always gives presents that are off the charts. Her book *Here Begins the Dark Sea* is out now

Brave new words

Science often gives rise to novel additions to our vocabulary. **Liz Else** introduces nine new or reinvented terms that express emerging concepts, trends or emotions

Ageotype

In 2020, Michael Snyder, a geneticist at Stanford University in California, discovered that we tend to age along four different pathways. He found that the biological signatures associated with ageing are mostly found in four parts of your body – your kidneys, liver, immune system and general metabolism – with one or two of these systems ageing faster than the rest.

Snyder reckons figuring out your "ageotype" can lead you towards the best strategy to target your predominant ageing pathway, meaning you live healthier for longer. Liver agers, say, might consider laying off the booze. Metabolic agers, meanwhile, should focus on exercise.

In any case, we might expect the term to rise to prominence, at least within the circles that obsess about this stuff, on the basis that it is at the vanguard of efforts to personalise anti-ageing interventions.

Agrivoltaics

The next time you find yourself walking in the countryside, you may spot some rather odd-looking fields. Some will have crops co-existing with great swathes of solar panels, while others will be full of livestock sheltering or grazing under a photovoltaic canopy. What you would be looking at are "agrivoltaics", a term that describes solar energy installations designed to work alongside crops or livestock.

Inevitably, some people argue that solar farms blight the landscape and change the nature of rural communities. But in North America, proponents of agrivoltaics are working to convince them that solar farms can help to restore disappearing prairies. In any case, the term will surely stick around because it captures a new frontier in the battle over the transition to renewable energy.

Antevernals

ANDY MARTIN

The nature writer Robert Macfarlane has written that this term, originally coined by environmental journalist Michelle Nijhuis, describes "spring flowers that bloom uncannily early in the year due to changes in climate, suggesting an eerie time-out-of-jointness".

Like so many of today's neologisms, the word captures a facet of the changing environment. Last year, researchers found that UK spring flowers are opening nearly a month earlier than they did before 1986, because of climate change. The scary thing, says Ulf Büntgen at the University of Cambridge, who was part of the team, is that just 1°C of global warming can translate into flowering taking place a whole month earlier. Where does that leave insects, birds and other animals that live in sync with the flowering of specific plants?

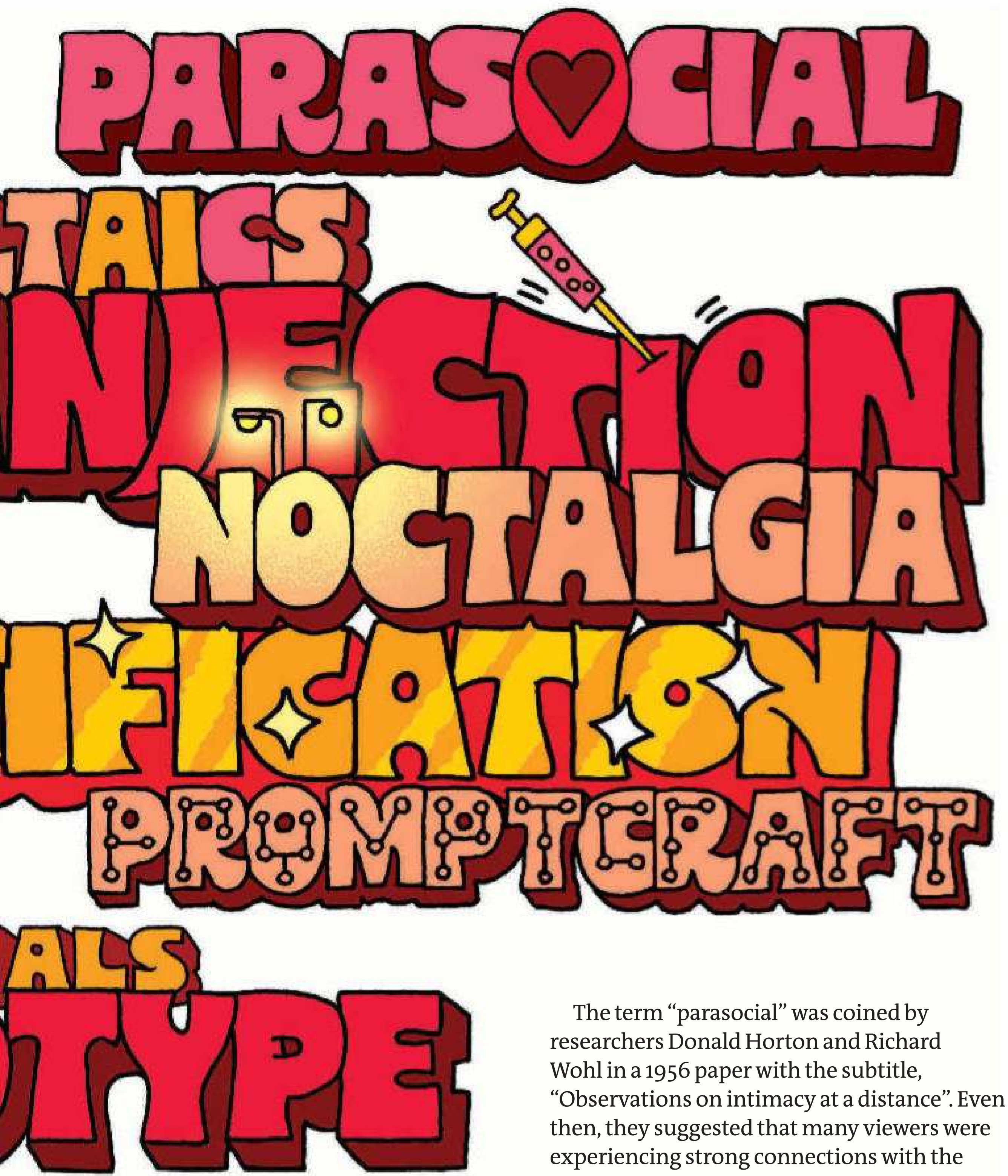
Marsification

The Bureau of Linguistic Reality (BLR) is a participatory art project that asks members of the public to help devise neologisms capturing how we feel about climate change, biodiversity collapse and other transformations. Among their inventions is "marsification", an attempt to describe the increasing use of "techno-utopian fantasy to transcend dire physical and ecological realities on Earth".

The term is a send-up of the idea that we can colonise the Red Planet once our blue world becomes hostile to life. In the BLR's interpretation, however, marsification captures a fast-developing ideology that presents technological fixes as "universally beneficial solutions", while ignoring any of the tricky social, political, economic or spiritual aspects of complex problems. Moreover, the BLR adds, it describes attempts "to solve a problem in the most statistically unlikely and unselfconsciously grandiose way possible".

Noctalgia

Earlier this year, Aparna Venkatesan, an astronomer at the University of San Francisco, and John Barentine at Dark Sky Consulting in Tucson, Arizona, wrote to the journal *Science* in response to an article exploring the problem light pollution poses for astronomy. Considering that – alongside Elon Musk's growing fleet of low-orbiting satellites – the duo coined the term "noctalgia" to express what they called "sky grief" for the "accelerating loss of the home environment of our shared skies, a disappearance felt globally". As we lose our ability to see the night sky clearly, they wrote, we are "witnessing loss of heritage, place-based language, identity, storytelling, millennia-old sky traditions and our ability to conduct traditional practices



grounded in the ecological integrity of what we call home".

Astronomers are pushing for regulation to mitigate ground-based light pollution. But Venkatesan and Barentine argue that the UN should designate the skies as "intangible cultural heritage" and expand the "rights of nature" legal theory, which proposes inherent rights for ecosystems and species, to help provide a framework for action.

Parasocial

Parasocial interaction theory seeks to make sense of a phenomenon in which people interact with celebrities, fictional characters, influencers and more as if they were in a genuinely reciprocal relationship with them.

The term "parasocial" was coined by researchers Donald Horton and Richard Wohl in a 1956 paper with the subtitle, "Observations on intimacy at a distance". Even then, they suggested that many viewers were experiencing strong connections with the characters in TV shows like *The Lone Ranger*.

Today, the term is acquiring new significance as people spend ever longer on social media, which tends to encourage the illusion that we can engage in relationships with people we can't truly interact with. We can expect the phenomenon to continue because, these days, many streamers – influencers who broadcast live – are deliberately seeking to exploit it.

Promptcraft

Otherwise known as prompt engineering, this term has two meanings. For the companies that make generative artificial intelligence tools, such as ChatGPT, it refers to the task of training them to deliver more accurate and relevant responses to the questions people pose. For the rest of us, it pertains to the art and science of perfecting the prompts you feed the AIs to get the best possible answers.

As with search engines, there is a knack to writing an effective prompt, and the internet is overflowing with hints and tips. Many experts argue that promptcraft will be a key skill as generative AI becomes an increasingly important part of many jobs. But the prominence of "promptcraft" might be fleeting because generative AI will inevitably become more adept at understanding even ham-fisted queries.

Solastalgia

Coined by philosopher Glenn Albrecht to describe the distress caused by environmental change, "solastalgia" describes "the homesickness you have when you are still at home, in Albrecht's words, as the natural world you knew disappears before your eyes.

Solastalgia is often caused by climate change. In one paper, Albrecht explores the experiences associated with persistent drought in rural New South Wales, Australia, and large-scale, open-cut coal mining. But it can be triggered by many things, including pollution and deforestation. The only good news, such as it is, is that some suggest solastalgia might have an adaptive benefit: like other "climate emotions", talking about it may help people become more resilient.

Thinjection

"Are you tempted by a thinjection?" That was the question posed earlier this year in *Women's Health* magazine, referring to a sensational new weight-loss drug called semaglutide (also known as Wegovy). The drug has attracted an immense amount of attention, not only as a result of endless speculation over which celebrities are using it, but also because "thinjections" have the potential to make obesity history.

It works by mimicking the effects of a hormone called GLP-1, which slows the passage of food through the gut and acts on the brain to suppress appetite. It is remarkably effective: in clinical trials, a weekly injection caused participants to lose 15 per cent of their body weight on average within 68 weeks. New and improved versions, which require fewer injections, are already in the pipeline. ▮

Liz Else welcomes your parasocial interactions

The science of ‘food bridging’

Culinary scientists may have cracked the riddle of why unlikely food combinations sometimes work. **Stuart Farrimond** tests the idea by preparing an unusual festive meal for *New Scientist* staff

SOME foods are made for one another. From the comforting cuddle of mozzarella, tomato and marjoram atop a pizza to the tantalising trinity of ginger, garlic and soy sauce that make East Asian dishes sing, some combinations seem so natural that it is difficult to imagine a world without them. And yet for centuries, gourmands and academics have been confounded by why some foods harmonise so well.

In 1992, chefs Heston Blumenthal and François Benzi hit the lab to try to solve this culinary riddle. They happened upon the idea that foods that taste good together also share many volatile flavour compounds – the aroma-carrying chemicals that rise up into the back of the nose to create the perception of flavour on the tongue. Their findings were validated in 2011, with a study that analysed 56,498 recipes from different international cuisines.

Yong-Yeol Ahn at Indiana University and his colleagues used the data to construct a network model, a complex map of the relationships between all of the recipes’ ingredients and the flavour compounds they shared. This confirmed that recipes from North America and western Europe do tend to pair ingredients that share flavour compounds.

“Flavour pairing theory” made waves in the culinary world, with food manufacturers dedicating resources to applying the idea to their products and start-ups tapping into open-source data on flavour compounds to predict what the next big food trend would be.

And yet, the concept was fundamentally flawed: it soon became apparent that it didn’t apply to many recipes from Eastern cuisines. Now, a new network model offers a solution that could unite all food flavours once and for all. As a doctor turned food specialist, I decided to put it to the test by creating a festive Christmas meal like no other.

The original flavour pairing theory neatly explained why coffee and chocolate is a match made in heaven: they share a legion of roasted, nutty and earthy flavour compounds, such as pyrazines. And it helped us create a range of whacky food pairings. Chocolate and blue cheese share at least 73 flavour compounds, for instance, which is why a blob of Roquefort on a cube of dark chocolate really does taste good.

But the data also revealed that Indian, South-East Asian, West African and some southern European cuisines typically don’t pair ingredients with shared flavour compounds. In fact, they do the opposite: they tend to combine ingredients that are least likely to share such compounds, such as lamb and cinnamon or fish sauce and tamarind. These are combinations the flavour pairing hypothesis says should clash, but are truly delectable, as everyone who has tried an authentic biryani or pad thai will know.

The answer came, surprisingly, from a major Spanish communications firm, Telefónica,

DAVID STOCK

DAVID STOCK

Guests enjoy a main course of turkey, peanuts and chocolate

“Garlic and strawberry share few flavours but beef can act as a bridge”

that had long been exploring ways to use its expertise in network science in other sectors. It tasked researcher Tiago Simas, now at the Central University of Technology, Arts and Design in Madrid, Spain, and his colleagues with looking again at the vast, sprawling network of flavour connections seen in the world's cuisines. They subsequently teamed up with legendary Spanish chef Ferran Adrià, who ran the three Michelin-starred restaurant, El Bulli, until it closed in 2011.

The team reanalysed the original flavour pairing network. Within the model, each ingredient is represented as a "node", and the connections between nodes indicate the sharing of flavour compounds, thus mapping out the relationships between ingredients across various dishes. The strongest nodes are those that share numerous flavour compounds with many other ingredients, giving them a versatility that makes them likely to be key components in multiple dishes.

Simas and his team discovered that recipes with incompatible ingredients use a third ingredient that shares numerous flavour compounds with both the incongruent foods. They called it food-bridging. Their analysis suggested that the most harmonious pathway between two ingredients may not be the most direct one. In the original analysis focusing on direct connections, familiar ingredients like cocoa, coffee and cheeses had emerged as the most crucial nodes in Western cuisines. The bridging analysis elevated teas, wines, tomatoes and a plethora of less familiar ingredients as key nodes that connect seemingly incompatible ingredients.

For example, while garlic and strawberry share few flavour compounds with each other, both have strong relationships with roasted beef. Intriguingly, a more circuitous path via roasted onion and Bantu beer, common throughout Africa, could further enhance their compatibility, potentially making for a more flavourful and complex dish.

Problem solved? Not quite. Up against the flavour bridging enthusiasts are an equal number of critics in both the academic and culinary worlds. One major issue is the bridging network's simplicity. It ignores each ingredient's texture, fat content, relative saltiness, sweetness, sourness and savouriness, and doesn't consider the specific concentrations of aroma compounds in each ingredient. Another problem is that the concept doesn't define the minimum number of shared compounds that are required for greatest palatability.

There was only one thing for it: I needed to test the idea for myself. So I decided to cook up an experimental festive feast. The idea was to incorporate pairs of foods that clashed horribly and see if they could bridged with a third ingredient to create delicious new combos. I enlisted adventurous *New Scientist* staff Obomate Briggs, Finn Grant, Joshua Howgego and Clare Wilson to judge my culinary creations, and they brought a blend of scientific rigour and festive cheer to the table. The results speak for themselves.

WELCOME DRINK

Champagne with chestnuts

Every Christmas party needs a welcome drink, and champagne seems befitting. Boasting more than 600 different flavour compounds, its bright acidity and hints of pear, green apple and citrus mean that champagne is awash with potential fruit pairing partners. The festive chestnut, however, is way down the list, making it a suitably unnatural partner for my experiment. Scrutinising flavour compound databases revealed, however, that both champagne and chestnuts share many volatiles with pineapple, which should harmonise the two.

To extract and concentrate flavour from the chestnuts, I opted to make a simple syrup by simmering a cup of chestnuts with equal amounts of water and sugar. I added a tablespoon of this syrup to a 50:50 mix of champagne and pineapple juice poured into a champagne glass and voila: pineapple-chestnut fizz!

Knowing beforehand that this was an experimental menu, my guests seemed surprised to be greeted with a pleasantly refreshing cocktail. Let's hope it isn't downhill from here.

RESULT: A charming boozy introduction
Average score: 7 out of 10

New Scientist video
Watch the short film about our food-bridging feast experiment youtube.com/newscientist

MAIN COURSE
Roast turkey with chocolate cake

The only option for our feast's centrepiece was turkey, the meat everyone loves to hate. Notoriously dry owing to broiler breeds' lack of fat, I set myself the challenge of trying to pair it with my all-time favourite Christmas dessert: a chocolate Yule log. Fortuitously, sweet-toothed researchers had already analysed the volatile compounds in chocolate cake – and sure enough, it makes for a terrible natural pairing with turkey according to the flavour pairing theory. However, referring to flavour data, I discovered that peanuts pair well with both turkey and chocolate, partly thanks to the nutty, toasted flavour compounds created through the roasting of cocoa and turkey skin.

To combine the three, I chose to blend soft peanut butter into a turkey gravy to give a satay-like twist. Texture would come from slicing and baking the chocolate cake into crunchy croutons to garnish the turkey.

RESULT: An almost unanimous hit. "The turkey and chocolate was an unexpected delight," says Josh.
Average score: 8 out of 10

SIDE DISH
Brussels sprouts and Scotch whiskey

Love them or loathe them, no Christmas meal would be complete without Brussels sprouts. Their divisiveness is in part due to variations in the gene encoding the TAS2R38 bitterness receptor on the tongue, resulting in half of us finding their taste intolerable. I decided to pair this classic festive vegetable with the most famous of winter warming liquors, Scotch whiskey. Sharing scant flavour compounds, a bridge came in the form of apple, which shares 70 flavour compounds with whiskey, and more than 100 with the sprouts.

Sautéing Brussels until just tender is probably the most flavourful way to cook them. Left too long in a pan of boiling water, bitter-tasting glucosinolates turn into eggy smelling, sulphur-containing volatiles. Adding chunks of apple to the pan and moving them to one side, I sprinkled in a little sugar and a splash of whiskey to make a glaze, which I then used to coat the greens.

RESULT: A triumph for all except Brussels sprout-hating Obomate.
Average score: 7 out of 10

Cloves with Emmental cheese was a step too far for some

SIDE DISH
Cabbage with gingerbread

With my creative juices in full flow, I attempted an ambitious brassica and dessert combo in the hope of pepping up a rather dull vegetable. The peacemaker between the sweet and fiery gingerbread and bitter cabbage came in the form of golden raisins, which I simmered with small pieces of gingerbread in a little sugar water to make a sticky compote to serve atop gently braised, shredded cabbage.

RESULT: Too sweet for some, it was generally seen as a pleasing twist on this seasonal vegetable.
Average score: 6 out of 10

DESSERT
Cloves with Emmental cheese

As I considered the meal's conclusion, I turned my attention to the cheeseboard. Emmental has a place in my heart for its mild, slightly nutty flavour that goes great on a cracker. Working down my list of seasonal ingredients, cloves struck me as a particularly unlikely pairing. Cross-referencing with other ingredients, I was encouraged to see that beer would bridge the two admirably, sharing the sweet, creamy compound vanillin with the cloves, and chocolatey tetramethylpyrazine with Emmental. I needed a neutral medium to combine them into a dessert and my inspiration came from Betty Crocker's traditional bread pudding. I folded grated Emmental cheese into slices of bread soaked in egg, sugar and beer, then baked for 45 minutes before drizzling with a homemade clove syrup.

> **"Some of the flavour combinations blew my mind"**

RESULT: Mostly positive reviews were drowned out by howls of revulsion from Josh, who found the "disgusting" clove syrup too medicinal.
Average score 7 out of 10

While not every pairing won universal acclaim, my four guests seemed largely impressed. "Some of the flavour combinations blew my mind – sometimes in good ways and sometimes not so much," says Clare. Initially sceptical, Finn is now a convert to food bridging after finding himself "tucking into second helpings" of nearly everything. Obomate was also won over by the sweet main and the sticky clove syrup. Josh offered the most effusive praise, labelling the meal "a massive win", remarking on how each dish's flavours coalesced into "a delicious whole".

Whether these culinary successes were due to luck or intentional design remains an open question, but it was certainly a fun evidence-based twist on a traditional dinner party that anyone can try. I am willing to keep on experimenting. So, who's ready for my next gastronomic gamble: an avocado, broccoli and chocolate surprise? ▮

Stuart Farrimond is now thinking about the peppery potential of Easter eggs

The back pages

Quiz of the year Can you remember all the biggest science news of 2023? p74

Puzzles Try our cryptic crossword and festive puzzles p76

Puzzle and quiz answers Find out how well you did p78

Feedback Dreaming of a calcium carbonate Christmas p80

Twisteddoodles for *New Scientist* Picturing the lighter side of life p80

The science of cooking

Mulling it over

Some things just go together, like cinnamon and Christmas. So let's make some mulled wine, says **Sam Wong**

Sam Wong is assistant news editor and self-appointed chief gourmand at *New Scientist*. Follow him @samwong1

What you need

2 oranges
150 grams or ¾ cup caster sugar or granulated sugar
5 cloves
5 cardamom pods
1 cinnamon stick
Pinch of nutmeg
2 bottles of red wine

VALENTYN VOLKOV/ALAMY

WE ALL know red wine goes with beef, white wine goes with fish and lager is the ideal foil for a spicy curry. But can science explain why some drinks are a perfect match for certain foods?

One hypothesis for explaining flavour matches is that foods go together well if they share many aroma compounds (see page 70). But this theory has its critics, and in any case, different rules are likely to apply to food and drink pairings, when the two partners aren't usually in the mouth together at the same time.

In a study that asked wine and beer experts to suggest food matches, some pairings were thought to match because of a certain similarity in taste – for instance, acidic wines with acidic cheeses. In other cases, elements that are strong in different ways were said to balance one another – like salty cheese with sweet wine.

Sometimes, we appreciate a drink that can neutralise the aftertaste or mouthfeel that remains after we eat certain foods. For example, tea contains chemicals called saponins that help to wash out greasiness – which probably explains why my wife insists on a cup of tea with fish and chips. Conversely, eating cheese has been found to reduce the astringency of a red wine, perhaps because of an attraction between fat droplets and tannins.

Some pairings are best avoided because the two elements interact in an undesirable way. A 2009 study reported that some red wines containing high levels of iron led to an unpleasant, fishy aftertaste in scallops. For some people, artichokes can make wine taste sweet, due to a chemical called cynarin. This molecule binds to sweet taste receptors without activating them. When you sip a drink and the cynarin is washed away, this frees up the receptors and triggers a sensation of sweetness.

While these chemical and perceptual phenomena play a role in some successful combinations, there is no doubt our enjoyment of food and drink pairings is partly down to familiarity and cultural context. Sometimes, we might want to choose a drink that matches the occasion, rather than the food being served. According to a study carried out in Germany, participants found the smell of cinnamon more pleasant at Christmastime than in the summer, and also associated orange and cloves more strongly with Christmas.

This seems like a good enough reason to make mulled wine. Start by infusing the spices in a syrup: add the sugar and spices to a large saucepan along with the orange peel and juice, then add just enough wine to cover the sugar. Heat until the sugar dissolves, then simmer until you have a thick syrup. You can store this syrup and use it later, or add the rest of the wine, heat gently and serve immediately. Blue cheese would be a fine companion. ▮

The science of cooking appears every four weeks. Share your cooking successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistCooking

Up next

60-second psychology

These articles are posted each week at newscientist.com/maker

Science to remember

Whether it is a new way to shake a martini or what happens to spiny lava lizards when temperatures rise, there was plenty of weird science news in 2023. **Bethan Ackerley** is here to quiz you on it

ALEC LUHN

1 When the holiday season rolls around, one topic is always at the forefront of our minds: the mating habits of frogs. But what didn't we learn about these amorous amphibians this year?

A Female frogs play dead to avoid mating

B Male frogs have been mating with the wrong species for over 200 million years

C Female frogs yell at coercive males

D Male frogs often accidentally poison themselves during mating

2 In September, a security researcher revealed that a data leak from the International Space Station meant it was possible to track when astronauts did what?

A Sneezed

B Slept

C Urinated

D Laughed

3 What unique appendage of sharpshooter insects did we report on in February?

A Their anal catapult

B Their swivelling stinger

C Their perineal horn

D Their plasma-firing claw

4 In June, scientists announced they had made a robot arm with a specially adapted hand to grip awkward objects or grasp things underwater. But what was the hand made of?

A A living crustacean

B Spider silk

C Cigarette butts

D Aubergines (eggplants)

5 In July, the RRS Sir David Attenborough prepared for its first expedition to Antarctica. It will be researching copepods, a kind of zooplankton whose collective weight is how much?

A Half that of the entire human population

B The same as that of the entire human population

C Ten times that of the entire human population

D One-hundred times that of the entire human population

STUDIOTOUCH/SHUTTERSTOCK

SIMON BELCHER/ALAMY

From top: a fruit fly, possibly playing Wordle; how many UK lottery tickets to ensure a win?

6 In November, physicists invented a new way to shake a martini that produces what shape on the drink's surface?

A A thumbs up

B A four-leaf clover

C A heart

D A skull

7 In August, we reported on evidence that fruit flies seem to be capable of playing, but what activity did they appear to enjoy doing?

A Rolling wooden balls

B Riding a carousel

C Playing Wordle

D Arranging bricks

8 We learned a lot about octopuses this year, but what didn't we discover about these cephalopods?

A They replay skin patterns from when they are awake while they sleep

B Their ink contains a compound that kills cancer

C They edit their genetic code to adapt to colder water

D They take revenge on predators that harm them

9 Buying how many tickets guarantees a win in the UK's "Lotto" lottery, as two mathematicians showed in July?

A 27

B 55

C 89

D 103

10 What makes the Sverdrup-Henson crater special, according to research published in September?

A It is the best place to build a moon base

B It was made by a meteorite suspected to have caused a mass extinction

C Its terroir makes it the best place to grow red wine grapes

D It is hidden beneath Rhode Island

11 Many species thought lost were rediscovered by science in 2023, but which of the following wasn't?

A Attenborough's long-beaked echidna

B The splendid poison frog

C The Pernambuco holly

D The strange big-eared brown bat

12 There were plenty of entirely new-to-science species too. Which of the following was discovered this year?

A The dragon macaque

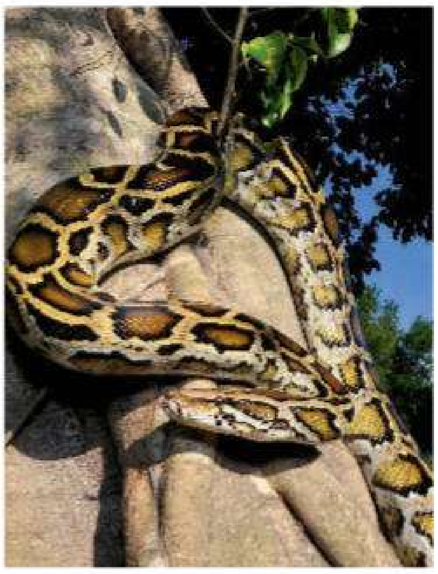
B The goblin bee

C The demon catshark

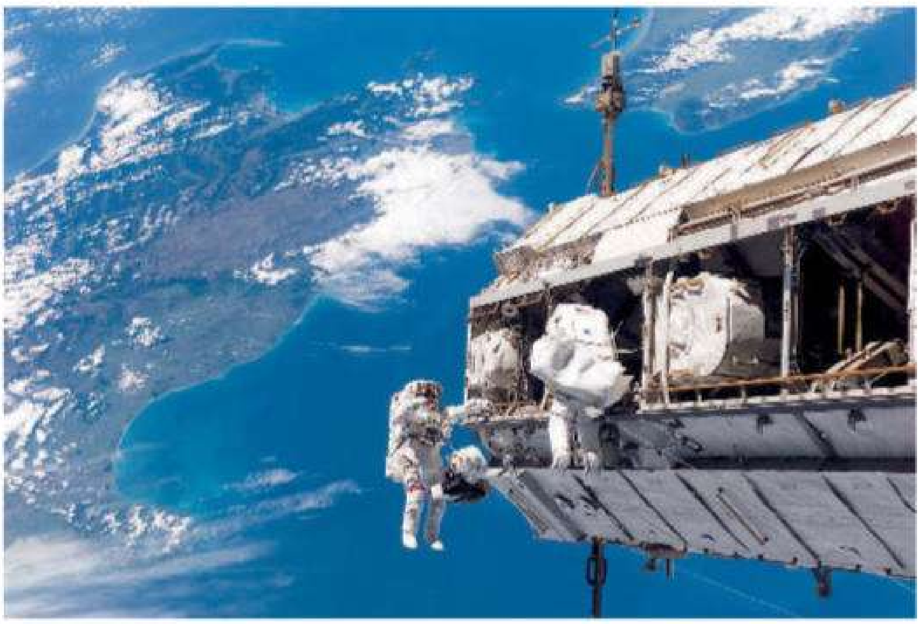
D The yeti moth

VLADIMIR TURKENICH/SHUTTERSTOCK

OLENA YEROMENKO/ALAMY


MARK CONLIN/ALAMY

O. MARTINSEN-PANAMA WILDLIFE/ALAMY


STS-116 SHUTTLE CREW/NASA

Clockwise from top left: an octopus, possibly plotting revenge; how long did it take you to decide this Chinese buffet was food?; a Burmese python; what are these astronauts up to at the International Space Station?; mating spiny cochran frogs; the British Antarctic Survey's ship, the RRS Sir David Attenborough

13 What has been spotted breaking Isaac Newton's third law of motion, as we reported in October?
A The mantis shrimp
B Human sperm
C Maxwell's demon
D The LK-99 superconductor

14 We learned a lot about rats this year, but what didn't we discover about these rodents?
A They squeak with happiness when they see another rat
B They have an imagination
C They are fooled by the Asahi illusion, just like humans
D They prefer thrash metal over other musical genres

15 In April, an itinerant Burmese python in Florida laid a record number of eggs for its species – how many?
A 84
B 88
C 92
D 96

16 What could give away a fake passport image made from two morphed photos, as we learned in November?
A The tips of the ears
B Overly smooth eyebrows
C Uneven beard density
D Shadows on the eyes

17 In October, researchers used AI to decipher a word in a charred, unopened ancient scroll from the Roman city of Herculaneum. What was the word?
A Porphyras, meaning purple
B The name Valeria
C Bovi, meaning cattle
D Nereides, meaning sea nymphs

18 We like to bring you the biggest news in science, but which of these sizeable stories didn't we feature?
A The largest number of entangled qubits in a quantum computer
B The largest giraffe skeleton ever found
C The largest quasicrystal yet created
D The largest marsquake on record

19 At the other end of the scale, the smallest what was built in October?
A X-ray machine
B Mass spectrometer
C Seismometer
D Particle accelerator

20 Sticking with superlatives, archaeologists found the earliest known example of what this year, dating back 9000 years?
A Architectural plans
B A pie recipe
C A letter of complaint
D A message in a bottle

21 When exposed to warmer-than-usual temperatures, what do spiny lava lizards get less fussy about?
A Their food
B Their sexual partners
C Their living situation
D Their personal hygiene

22 In May, we learned migratory locusts release a compound called phenylacetonitrile – for what purpose?
A To treat fungal infections
B To stop other locusts eating them
C To communicate with their young
D To change sex

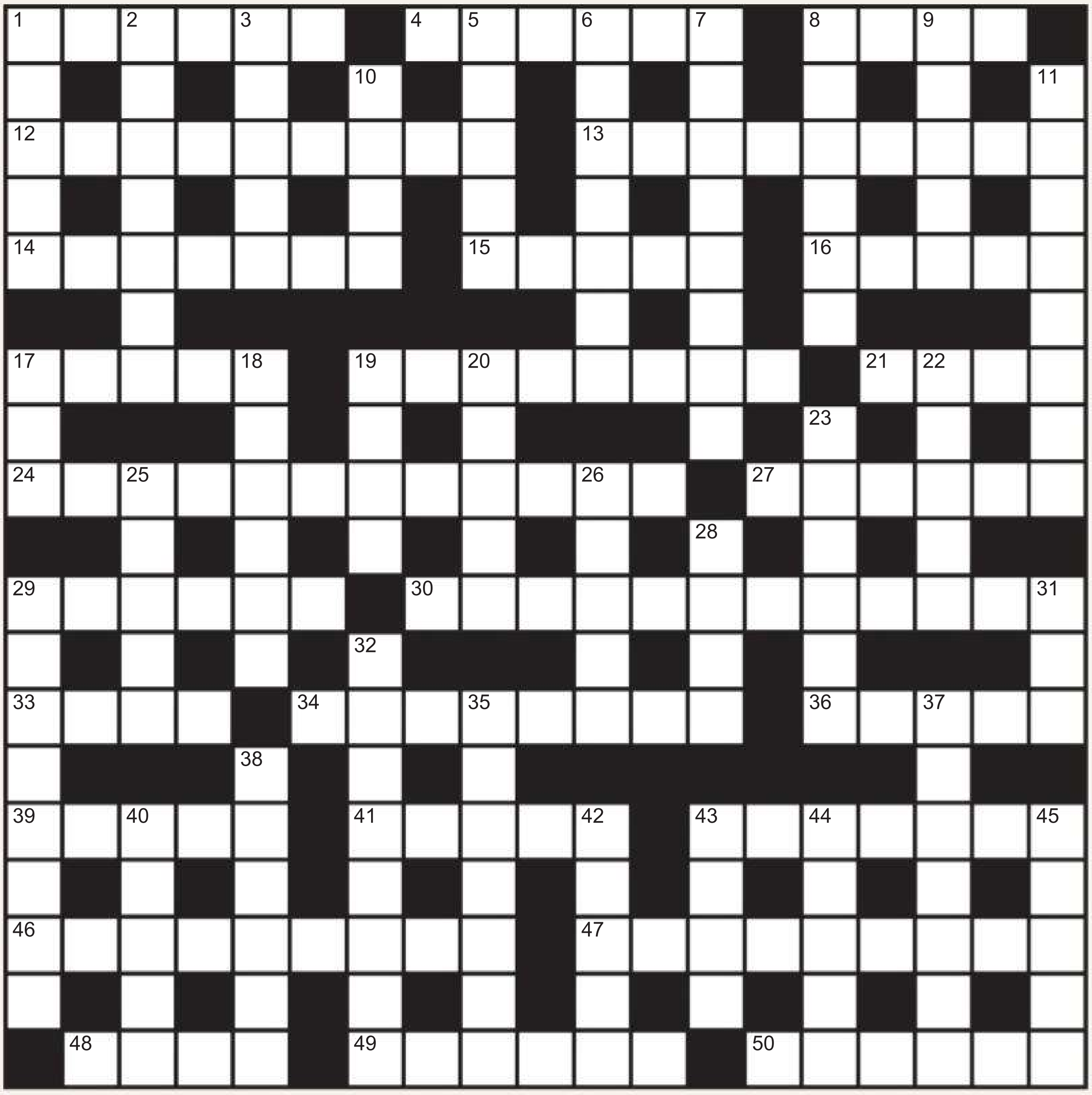
23 Staying with animal innovation, which of the following behaviours didn't we report on this year?
A Zebrafish make sunscreen to protect their embryos
B Birds use anti-bird spikes to make their nests
C Arctic foxes change their eye colour from summer to winter
D Orangutans can make two sounds at once like a beatboxer

24 As we learned in June, low-density plumes of magma beneath the Indian Ocean, just south of India, have created what?
A A mass breeding site for loggerhead turtles
B A new supervolcano
C A gravity "hole"
D A natural nuclear reactor

25 And finally, we learned in October that when looking at an object, it takes as little as how long for us to decide if it is food?
A 92 milliseconds
B 108 milliseconds
C 375 milliseconds
D 492 milliseconds

Answers on page 78

Cryptic crossword #125 *Set by Wingding*



Scribble zone

Our crosswords are now solvable online
newscientist.com/crosswords

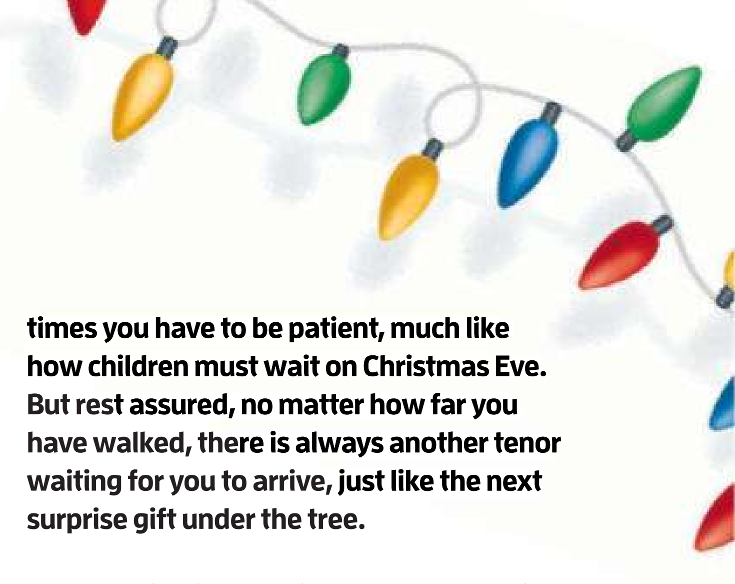
Answers and the next quick crossword in the next issue

For a guide on how to solve *New Scientist*'s cryptic crossword visit:
newscientist.com/cryptic

Twenty-one of the following solutions are linked to a theme; their clues don't include a definition.

ACROSS

1 Flowers compete with setter (6)
4 A piece of teaching equipment on a ship (6)
8 Fail to catch warm garment (4)
12 Deliver countries' aid packages (9)
13 Clique worked with beer after I left (9)
14 Kitchen tool starts to reek terribly (7)
15 Gettin' close, by the sounds (5)
16 Group from China designs revolutionary car (5)
17 Amazon half destroyed by old Brazilian leader, the former president (5)
19 Composed dawn tune that's not welcome (8)
21 Time to enter exam, quickly! (4)
24 Low-carbon way to get around Baku in no time, on a tour (8,4)
27 Waves cut off sources of anthropogenic noise (6)
29 Starter of liver wrapped in bacon, perhaps? (6)
30 Dismantle cargo on a hill – that's strong stuff (5,7)
33 Instrument is reportedly stolen goods (4)
34 Nigeria's border soldiers finally sent after gold decoration (8)
36 At night, kiss stretchy material (5)
39 Half of gang drink fish sauce (5)
41 Some of Magritte's landscapes (5)
43 Stay 40 per cent sober with reporter? Not half! (7)
46 Optical phenomenon made by two big cats, one skinned (9)
47 Country gripped by awful colonic blockage (9)
48 Extra changing hands (4)
49 Issue around carbon monoxide (6)
50 Amphibian running (6)



DOWN

1 Desire endless, novel thrills (5)
2 Lad with acne treated (7)
3 Small amount of toxin in lake (5)
5 Aromatic plant is in research facility on the rise (5)
6 Record last parts of lecture on white stuff (7)
7 Nitrogen reacted unexpectedly in container (8)
8 Rodent eats top of steamed pudding (6)
9 Distant poster (5)
10 Not entirely revolting (4)
11 Sound of physicist with large amount of small organisms (8)
17 Gotham, regularly cleared (3)
18 Reach a tall tree and imagine new beginnings (6)
19 Component used in ammunition (4)
20 Drug added to strange brew (5)
22 Body part that's initially elevated (5)
23 Friend going around southern California (6)
25 In Paris, a bed is dark (5)
26 Potassium degraded fine tool (5)
28 Can you repeat that for the audience? (4)
29 Zuckerberg, for one, climbs over Italian festive dessert (8)
31 Oddly loud on social media platform (3)
32 Complex molecules represented in poster (8)
35 Toxic chemical can rise when stirred (7)
37 Climbing teacher interrupts salesperson and traveller (7)
38 Finnish city expels leader (6)
40 Perhaps Nelson gave up house for relationship (5)
42 Article on crop nut (5)
43 Disgusting criticism wastes time (4)
44 Precious thing in hearing (5)
45 Trimmed design in one fabric (5)

Headscratcher

#252 Santa clocks

set by Brian Hobbs

'Twas the night before Christmas,
when all through the house,
Not a child was sleeping; just me and my spouse.
For Santa was coming, and kids needed proof
So they listened intently for hoofs on the roof.

They had all been asleep
when we turned out the light,
But each woke up once in the course of the night.
First Jill, and then Jennifer, Jimmy and Jake
Spent no more than 6 hours lying awake.

The only sounds heard were the gentle tick-tock
And the hourly chimes of the grandfather clock.
At the top of the hour, the clock would make note
By chiming the number the hour hand showed.

As each child listened, they passed the time
By totalling up the grandfather clock chimes.
They tallied them to a particular number
'Til finally succumbing to sleeping and slumber.

None of the kids, in regards to the timing
Fell asleep or awoke while the hour was chiming.
Through different hours did each child count
Yet they each wound up totalling
the same amount.

"What are the odds?" we all asked one another.
This number they counted is yours to discover
Are there four sets of consecutive hours
That make the same sum?
Use your deductive powers!

"Next year," the kids thought,
"we won't even try it;
Santa Claus seems to be terribly quiet."
By evening the kids had all leapt out of sight
"Merry Christmas, but we're off to bed,
so good night!"

#253 Two tenors

set by Daniel Griller

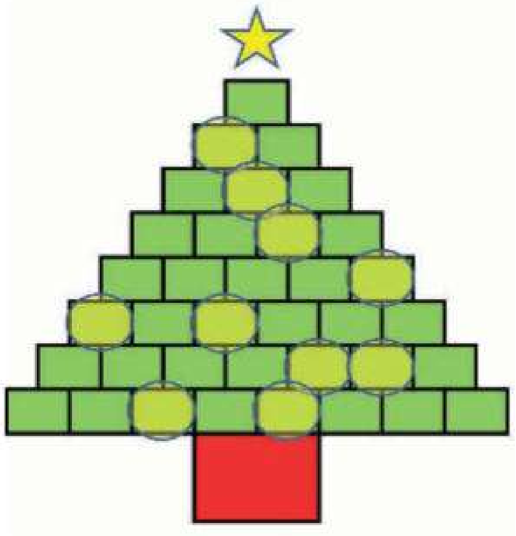
Starting at the number 1, as you embark on a festive stroll along the number line, you will, from time to time, land on whole numbers whose digits sum to a multiple of 10; like 46 or 785, or 90939. Let's call these special numbers "tenors".

Sometimes, the gap from one tenor to the next is small, like the time it takes for Santa's sleigh to fly across the sky, while at other times you have to be patient, much like how children must wait on Christmas Eve. But rest assured, no matter how far you have walked, there is always another tenor waiting for you to arrive, just like the next surprise gift under the tree.

The question is: what is the largest possible gap between one tenor and the next, and how soon into your walk will you encounter such a gap?

#254 Elemental

set by Paul Board



PAUL BOARD

To crack this puzzle, each cell may have one or two letters in it, and each of these must constitute an elemental symbol. Each clue corresponds to the relevant line of the tree. Once you have solved the clues and completed the tree (including the baubles), rearrange the letters in those baubles (without switching the letters in a two-letter elemental symbol) to form something you may use in your Christmas cooking or in a potpourri (two words: 8,5). You might be advised to have a copy of the periodic table to hand!

1 Said three times when Santa Claus laughs (2)
2 __ Man, a character in *The Wizard of Oz* (3)
3 Winter precipitation and the surname of a chemist and novelist famous for his lecture on "The Two Cultures" (4)
4 Nuts that form the basis of marzipan in a Christmas cake (7)
5 German chemist who was born on Christmas Day 1876 and awarded the Nobel prize for chemistry in 1928 (7)
6 Alcoholic component of Buck's Fizz (9)
7 *The* __, a ballet by Pyotr Ilyich Tchaikovsky, often performed at Christmas (10)
8 One of the Christmas gifts from the three wise men (12)

Answers to these puzzles, plus the solutions to 9 December's puzzle and crossword, on page 78

Quiz of the year

Answers

1 D - Male frogs often accidentally poison themselves during mating
2 C - Urinated
3 A - Their anal catapult
4 A - A living crustacean
5 C - Ten times that of the entire human population
6 B - A four-leaf clover
7 B - Riding a carousel
8 D - They take revenge on predators that harm them
9 A - 27
10 A - It is the best place to build a moon base
11 B - The splendid poison frog
12 C - The demon catshark
13 B - Human sperm
14 D - They prefer thrash metal over other musical genres
15 D - 96
16 B - Overly smooth eyebrows
17 A - Porphyras, meaning purple
18 B - The largest giraffe skeleton ever found
19 D - Particle accelerator
20 A - Architectural plans
21 B - Their sexual partners
22 B - To stop other locusts eating them
23 C - Arctic foxes change their eye colour from summer to winter
24 C - A gravity "hole"
25 B - 108 milliseconds

How did you do?
18-25 - Is that a stack of *New Scientist* magazines we see beside you? Bravo! You clearly know your sciencey stuff.
12-17 - The unmistakable whiff of knowledge is emanating from you. Congratulations!
6-11 - Hmm. Feels like a heady combination of luck and educated guesses. Still, it is the taking part that counts, so well done.
0-5 - Oops. Even guessing every time should have delivered six points, on average. If you don't already have one, perhaps try a *New Scientist* subscription in 2024!

#252 Santa clocks

Solution

They each counted 15 chimes, broken up like this: (12, 1, 2), (1, 2, 3, 4, 5), (4, 5, 6) and (7,8). Every odd number can be summed with two consecutive integers (such as 7, 8). Every number divisible by 3 can be summed with three consecutive integers (such as 4, 5, 6), and every number divisible by 5 can be summed with five consecutive integers (such as 1, 2, 3, 4, 5). The number 15 is an odd number that is a multiple of 3 and 5, and can also be made by summing 12, 1 and 2. That makes 15 the smallest number that can be summed in four ways with consecutive numbers on a clock. The next such number is 33, but that requires one child to count for over 7 hours, contradicting the "no more than 6 hours" that any one child was awake.

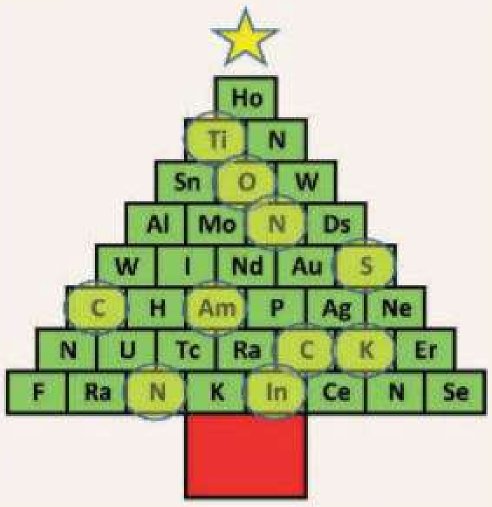
#253 Two tenors

Solution

The smallest tenor is 19. After this, in each block of ten numbers (20-29, 30-39 and so on), the digit sum increases one by one, so exactly one number in each block has a digit sum divisible by 10. That is, each block contains exactly one tenor. Given this, the biggest gap we could hope for is 19 – when the first number in one block is a tenor and the last number in the next block is also a tenor. It turns out this is possible, and the first appearance of such a gap is between 280 and 299.

#254 Elemental

Solution



The final answer is:
(C)(In)(N)(Am)(O)(N)(S)(Ti)(C)(K).

Cryptic crossword #124

(set on 9 December)

Answers

ACROSS
7 Read it and weep, **8** Talisman, **9** Tutu, **10** Tiny Tim, **12** Rheum, **14/2** Space Oddity, **16** Bladder, **19** Tier, **20** Username, **22** Wide-angle lens

DOWN
1 Zeta, **3** Ethmoid, **4** On end, **5** Switch, **6** Test tube, **11** Implicit, **13** Alveoli, **15** Cortes, **17** Dongle, **18** Dunno, **21** Monk

#251 Children of Quirkopia

(set on 9 December)

Solution

The answer is (b) the population is still divided 75 per cent male to 25 per cent female. This is true regardless of the make-up of individual families. To see why, imagine visiting the maternity hospital. There is a 75 per cent chance that the next baby to be born will be male. If so, then that family isn't allowed more children, but this is irrelevant to the midwife, who is awaiting the arrival of the next baby, which is also 75 per cent likely to be a boy. Each new baby's sex is independent of what happened previously, so the draconian policy has had no impact on the ratio of males to females; it merely reduced the birth rate.

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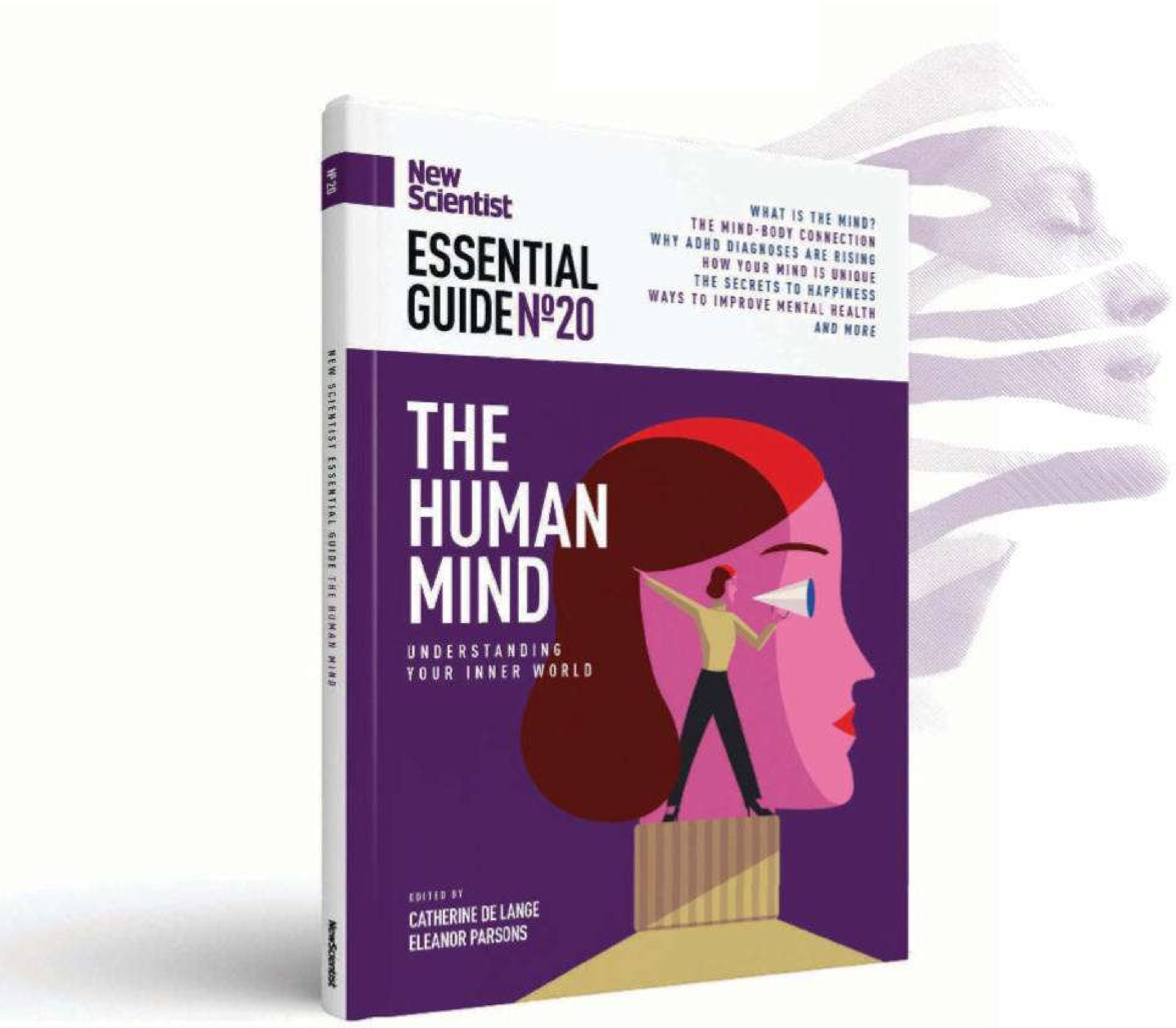

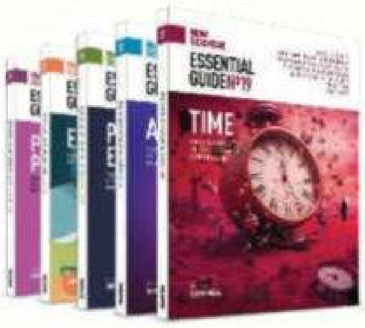

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Increasing perimeters

Some people are big on holidays – bigger than they were before those holidays. A team at the University of Castilla-La Mancha and the University of Valladolid, Spain, sized up some first-year undergraduate nursing students, then wrote about it in a paper called "Preliminary study of the increase in health science students' body mass index during the Christmas holidays".

The researchers assessed changes in the weight and waist circumference of 67 students during the course of Christmas vacation. They asked students to measure themselves on 23 December, the day before the holidays officially started, and again at two specified points during the break, then finally on 13 January, the day general university activities officially resumed.

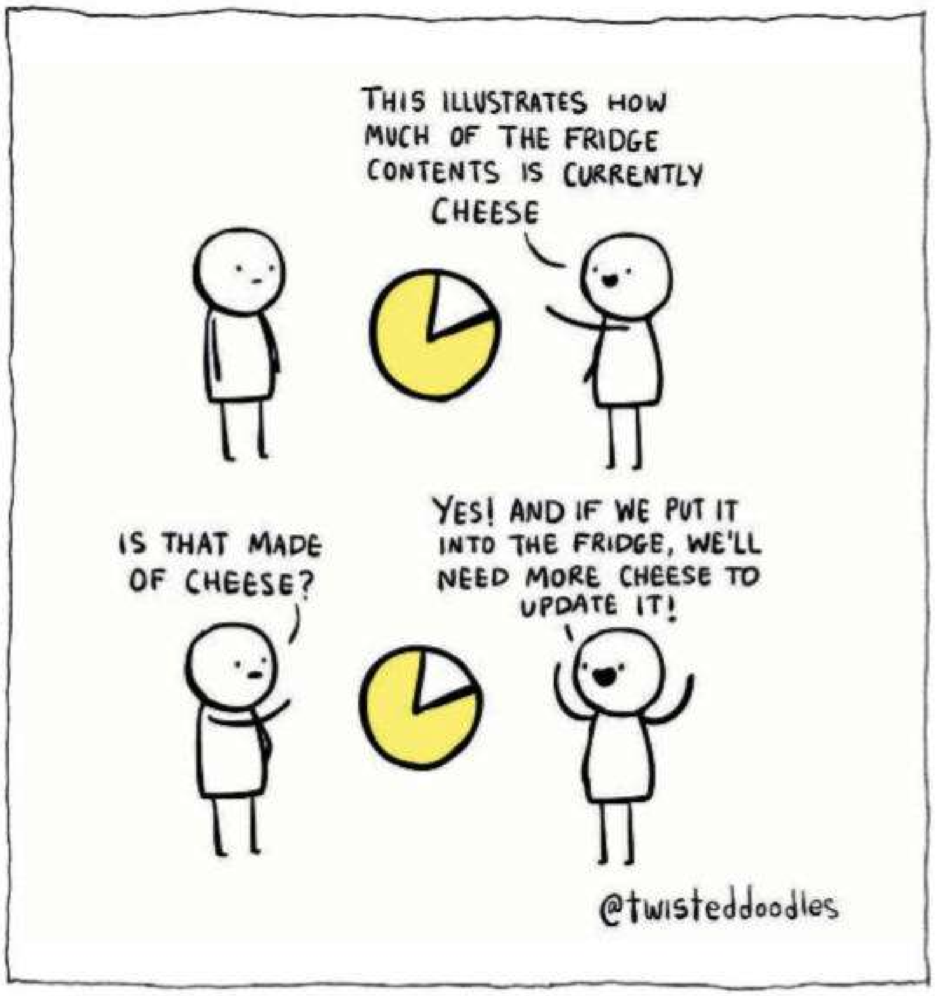
(Presumably the students were honest and accurate. However, the study includes the careful statement "This was a preliminary pilot study with self-reports. It is known that these reports tend to underestimate weight.") The self-reported numbers show that, on average, body weight went up by about half a kilogram during the holiday, then came back down by the return to campus.

The study says: "As a whole, the students who weighed more had a greater tendency to gain more weight, in the case of both males and females." What (not just how much) the students ate may, the study suggests, have played a sizeable role: "The students with a high-fat diet presented with a more pronounced change in weight."

What new hill of beans does this up-and-down poundage amount to? The study concludes: "Although the weight gain was not alarming, it does point to the possibility of weight gain among young adults during vacation periods."

What of the student waistline size (the study calls it "abdominal perimeter")? That increased, on average, by about a centimetre and stayed that way. In other words: post-holiday, people tended to be just a little stouter.

Twisteddoodles *for New Scientist*


THIS ILLUSTRATES HOW MUCH OF THE FRIDGE CONTENTS IS CURRENTLY CHEESE
IS THAT MADE OF CHEESE?
YES! AND IF WE PUT IT INTO THE FRIDGE, WE'LL NEED MORE CHEESE TO UPDATE IT!
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

A small holiday bite

Little things that happen during any holiday can, thanks to the timing, be especially memorable. So it is with the case of the snake that bit the genitals of a defecating man. G. H. Dijkema at Rijnstate hospital in the Netherlands and colleagues lay forth the details in a report called "Scrotal necrosis after cobra (*Naja annulifera*) envenomation".

Essentially, this is a simple tale. The team compresses the basic facts into a single sentence: "A 47-year-old otherwise healthy male was on holiday in a South African nature reserve, and while toileting, a snake struck from the toilet and bit his genitals."

Enough extra detail is added to fill two and a half pages, spiced up with three photos of the injured body part. The authors also add this kindly thought: "Our take home message? Always flush the toilet before sitting down in countries notorious for their snake population!"

A new holiday tradition

Some families like to gather to read aloud holiday stories, especially the Christmas tales written by Charles Dickens. But families who are tired of hearing the same old words year after year do have alternatives. Maybe the most profitable is to take a businesslike approach.

Yukyoung Kim has identified a heap of stories that – because no one is stopping you – you and your family can read to each other as you anticipate the arrival of New Year.

Kim compiled the material as the main chunk of a master's thesis at the College of Liberal Arts and Convergence Science in South Korea, giving it the title "Study on CEO New Year's address: Using text mining method". "CEO", as most holiday revellers know, is an acronym that stands for the phrase "chief executive officer".

Kim's summary of these New Year's stories is more businesslike than Dickens's summaries of his Christmas tales. Kim says: "This study analyzed the CEO New Year's addresses of major Korean companies… [I] analyzed 545 New Year's addresses published between 2012 and 2021 by the top 66 Korean companies in terms of market capitalization."

Many Korean CEO New Year's addresses are findable on the internet, or by sending a request in an admiring tone to the corporate offices. After an evening of hearing family members declaim these CEO stories, whatever happens during the next few days will feel like a rousing start to the year.

Muddy White Christmas

In contrast to snow blanketing the land in chilly climes, having a White Christmas in some warmer places is a matter of calcium carbonate ($CaCO_3$) precipitating in balmy waters. The $CaCO_3$ drops to the sea floor, coating it with thick, white lime mud.

Sam Purkis at the University of Miami, Florida, and team published a study about this, titled "Always a White Christmas in the Bahamas: Temperature and hydrodynamics localize winter mud production on Great Bahama Bank".

Though for Christmas Eve recitation the writing isn't quite Dickens (or Korean CEO), you can treat your relatives to the lyrical parts. This, for instance: "spatial heterogeneity in the degree of aragonite saturation is higher in the winter, and the zone of peak whitings is situated in an area of locally enhanced saturation state".

Accompanied by festive music and good cheer, your calcium carbonate White Christmas dramatic reading will turn the thoughts of all to better things. ▮
Marc Abrahams

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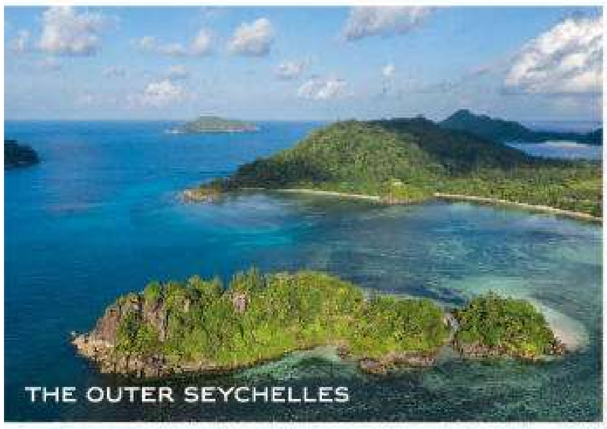
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ARCHIPELAGO, PORTUGAL

SEA LION,
GALAPAGOS,
ECUADOR

ON OUR WATCH

Hope can now be spotted across all our planet's seas and oceans. Sites are made into aquatic havens by local communities, to safeguard the richness and diversity of the ecosystems they depend on. Sylvia Earle's invaluable experience as an explorer and marine biologist continues to help further their goal, through her organisation, Mission Blue. Together, they have created over 130 Hope Spots and counting. Carrying a message of hope for generations to come. It is that vision, that dedication to a perpetual planet, which we are proud to stand by. **For as long as it is needed.**

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